WHATCOM COUNTY COMPOUND FLOOD VULNERABILITY ASSESSMENT

Prepared for
Whatcom County

June 2023


The Sandy Point Fire Station in January 2023

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Project Partners

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EXECUTIVE SUMMARY

Coastal communities have long been exposed to coastal hazards such as flooding, tsunamis, waves, and erosion, among others. As the global climate continues to warm and sea levels rise, many of these hazards will be exacerbated, becoming both more frequent and more intense. Climate change is expected to increase rainfall intensity and frequency, and compounded with higher sea levels, will lead to increased river flooding. Identifying, preparing for, and adapting to the threats posed by climate change, including sea-level rise and increased rainfall will be one of the defining challenges of the century.

Approach to Vulnerability Assessment

This study identifies coastal and lower Nooksack River areas of the county that may be most vulnerable to climate change-driven sea-level rise impacts and changing rainfall patterns and identifies strategies that may be applicable for addressing these risks. As part of the study, the County developed a Project Team to provide input and review. The Project Team included representatives from multiple departments and divisions within the County (e.g., watershed management, public works, climate action, emergency management, planning, river and flood, and stormwater, health), U.S. Geological Survey (USGS), Washington Sea Grant, Washington State Department of Ecology, Port of Bellingham, Lummi Nation, and the Cities of Bellingham, Blaine, and Ferndale as well as consultants from Environmental Science Associates (ESA), Coastal Geologic Services (CGS), and Northwest Hydraulic Consultants (NHC). The County also held three public meetings to identify existing risks and community priorities.

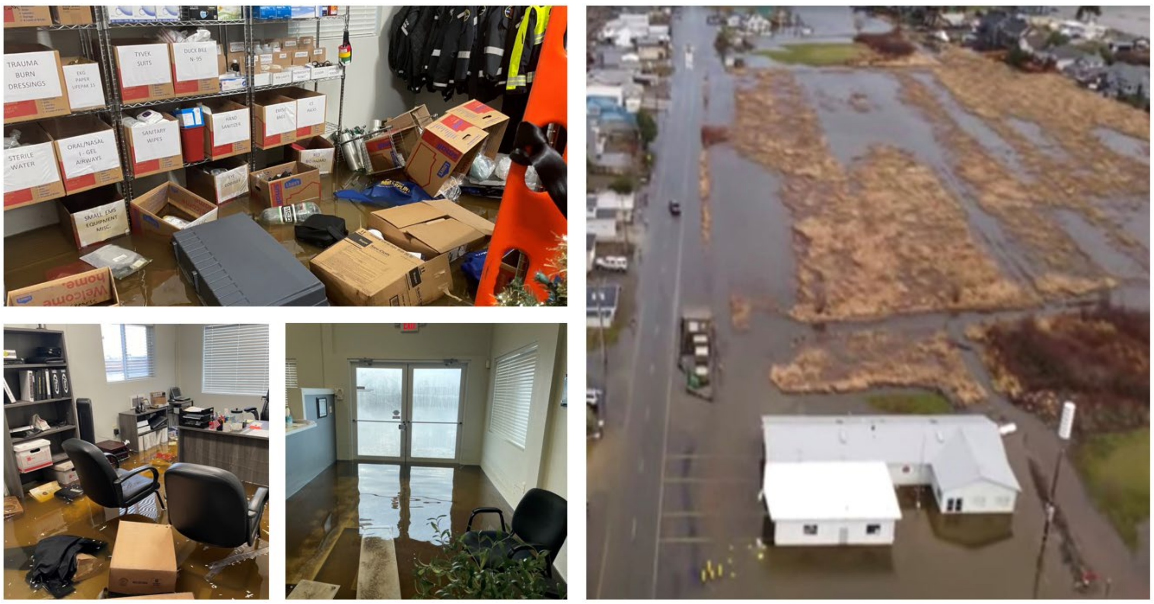
The analysis relies on modeling developed by the USGS as well as historic bluff erosion rates from CGS (2018). The USGS's Coastal Storm Modeling System (CoSMoS) provides storm-induced coastal flood hazard mapping for current and future conditions in addition to relative sea level rise. The USGS also recently completed a compound flood model for the Lower Nooksack River that considers greater precipitation and discharge and is combined with higher downstream water levels from the CoSMoS sea-level rise and storm surge data (Grossman et. al. 2023). Since sea-level rise is expected to create a permanent rise in ocean water levels that would shift the water's edge landward, increase rates of shoreline erosion, and exacerbate flood impacts, hazard zones have been developed that show the potential future extent of flooding and erosion in Whatcom County based on CoSMoS results for a range of sea level rise projections. These hazard zones can be viewed on Whatcom County's Compound Flood Viewer[1].

Existing Flood and Erosion Risks

Whatcom County contains numerous miles of low-lying shoreline and steep bluffs with both urban and rural development adjacent to a marine environment. In the Sandy Point community (**Figure ES-3**), coastal flooding has become a regular occurrence. In January 2023, king tides submerged the fire station with over 4 feet of water, and unlike past events, the water did not

1 https://www.arcgis.com/apps/instant/sidebar/index.html?appid=656f1dc771504a71acf0532053b72835

recede at low tide and flooded areas had to be manually pumped, resulting in over $1 million in damage (Communication with John Gargett, Whatcom County Sheriff's Office, Division of Emergency Management). In Birch Bay, the Birch Bay Drive and Pedestrian Facility project, constructed by the County, has reduced flooding from waves, but the low-lying community outside of the project boundaries still experiences inundation during king tides. In January 2022 and January 2023, flooding in Birch Bay caused approximately $0.5 million in damage each year (**Figure ES-1**).



SOURCE: Chris Elder (County), 2023 Whatcom County SLR Study

Figure ES-1
Sandy Point Fire Department Station #56 During December 2022 and January 2023 Storms

The first measured flood by the USGS occurred on January 25, 1935. Additional major floods along the Nooksack River occurred in 1951, 1975, 1989, 1990, 1997, 1999, 2002, 2004, 2009, 2020, and 2021. While the February 2020 "Super Bowl" flood was large and overtopped the Nooksack River's north bank at Everson and caused flood damage northward to Sumas and into lower British Columbia, the subsequent November 2021 floods were declared a presidential major disaster with damages in Whatcom County estimated at $150 million, including the displacement of thousands of families, damage to transportation infrastructure, and a tragic loss of life. (**Figure ES-2**).[2,3] Damages in British Columbia were significantly higher.

2 https://www.cascadiadaily.com/news/2022/nov/16/all-hell-broke-loose-one-year-post-flooding-in-whatcom-county/

3 https://www.whatcomcounty.us/4005/Emergency-Road-Repairs-Nov-2021-Flooding#:~:text=The%20historic%20floods%20in%20November,to%20roads%20damaged%20last%20November.

SOURCE: USGS 2023

Whatcom County SLR Study

Figure ES-2
Photos of Nooksack River Flooding

Whatcom County also experiences risk due to bluff erosion. Costs associated with bluff erosion are generally associated with the value of the asset lost (e.g., property, buildings, other development- ranging from millions to billions of dollars) as well as the costs to prevent further erosion from occurring where feasible and practical (e.g., costs associated with preventative measures such as armoring). According to the Whatcom County's Six-Year Capital Improvement Program, several projects associated with the prevention of further erosion are slated for the 2023-2028 program. Costs associated with these projects range from approximately $700,000 to $4,000,000 (Whatcom County 2022). Historical bluff recession rates in Whatcom County show recession rates ranging from 0.26 to 1.15 feet per year on the mainland, with an average of 0.58 feet per year across the county (CGS 2018).

Whatcom County Sea-Level Rise and Increased Precipitation Scenarios

For the purposes of this study, the County considered the high emissions scenario (RCP 8.5) to conservatively evaluate the vulnerability of County-wide assets. This scenario is conservative because it assumes emissions are not lowered in the future and will continue increasing. It is unlikely that emissions will exceed this scenario (Mauger et al. 2015).

The County selected 0.8 and 3.3 feet of sea-level rise to represent a short- and mid-term scenario based on the available CoSMoS results. The County also chose to consider a more extreme scenario of 6.6 feet of sea-level rise. The short-term scenario has a 10% or less chance of occurring by 2030-2050. The mid-term scenario has a 10% or less chance of occurring by 2070-2120. The long-term scenario has a 1% or less chance of occurring by 2090-2120.

Table ES-1 provides the combined CoSMoS and Lower Nooksack model scenarios used to develop the hazard maps for this study. The amounts of sea-level rise modeled in the Lower Nooksack model do not align exactly with the CoSMoS scenarios (0.9 and 3.1 feet). CoSMoS includes results for the 20-year event, but the Lower Nooksack model includes results for the 25-year event. Additionally, the 100-year event for the Lower Nooksack modeling was not available.

TABLE ES-1. MODELING SCENARIOS FOR WHATCOM COUNTY, WASHINGTON

UW CIG Projections			CoSMoS Scenarios		Lower Nooksack River Model Scenarios			FEMA FIRM
Anticipated Timeline	Probability of Exceedance by this Date		Sea-Level Rise (ft)	Coastal Return Period	Sea-Level Rise (ft)	Riverine Return Period	Discharge Increase	Riverine Return Period
Now	N/A	N/A	0	100-year	N/A	N/A	N/A	100-year
Short-term	10% or less by 2030-2050	50% by 2060	0.8	King Tide	0.9	N/A	N/A	N/A
				20-year	0.9	25-year	32%	N/A
Mid-term	10% or less by 2070-2120	50% by 2150	3.3	King Tide	3.1	N/A	N/A	N/A
				20-year	3.1	25-year	72%	N/A
Long-term	1% or less by 2090-2120	5% by 2150	6.6	100-year	N/A	N/A	N/A	N/A

Source: UW CIG 2018, USGS 2023, FEMA 2019

Future Hazards with Sea-Level Rise and Climate Change

The CoSMoS results show that a 20-year coastal storm event (the event with a 5% chance of occurring annually) combined with 0.8 feet of sea-level rise floods an area similar to the 100-year coastal storm event (1% annual chance of occurrence) today. With 3.3 feet of sea-level rise, king tides will flood an area greater than the 100-year coastal storm event today.

The Lower Nooksack model results show that the 10-year discharge event (event with a 10% chance of occurring annually) with 0.9 feet of sea-level rise floods an area similar to the 25-year discharge event today. Additionally, the 25-year discharge event (4% annual chance of occurrence) with 3.1 feet of sea-level rise floods an area similar to the 100-year discharge event today. In other words, based on these models:

- Today's 100-year coastal storm flooding (i.e., the FEMA Flood Insurance Rate Maps (FIRM) flood extent) will occur approximately every 20 years by 2040-2060 (assuming 0.8 feet of sea-level rise) and every year by 2080-2100 (assuming 3.3 feet of sea-level rise).
- Today's 25-year riverine flooding (like the 2009 flood) will occur approximately every 10 years by 2040-2060 (assuming 0.9 feet of sea-level rise).

- Today's 100-year riverine flooding (i.e., the FEMA FIRM flood extent) will occur approximately every 25 years by 2080-2100 (assuming 3.1 feet of sea-level rise).

Higher sea levels will also increase erosion of beaches and bluffs and increase wave attack at the toe of coastal bluffs, resulting in narrower distances between assets and the water. Beach and bluff erosion can also lead to flooding further inland.

These projections were used to create future hazard zones. The hazard zones were used to identify assets potentially at risk from sea-level rise and compound flood impacts (e.g., homes, roads, utilities) across the county. In the highly vulnerable Birch Bay and Sandy Point areas (**Figure ES-3**), the exposure, sensitivity, and adaptive capacity of each asset were evaluated to determine the asset's vulnerability.

Exposure

- Nature and degree to which a system is exposed to climate change.

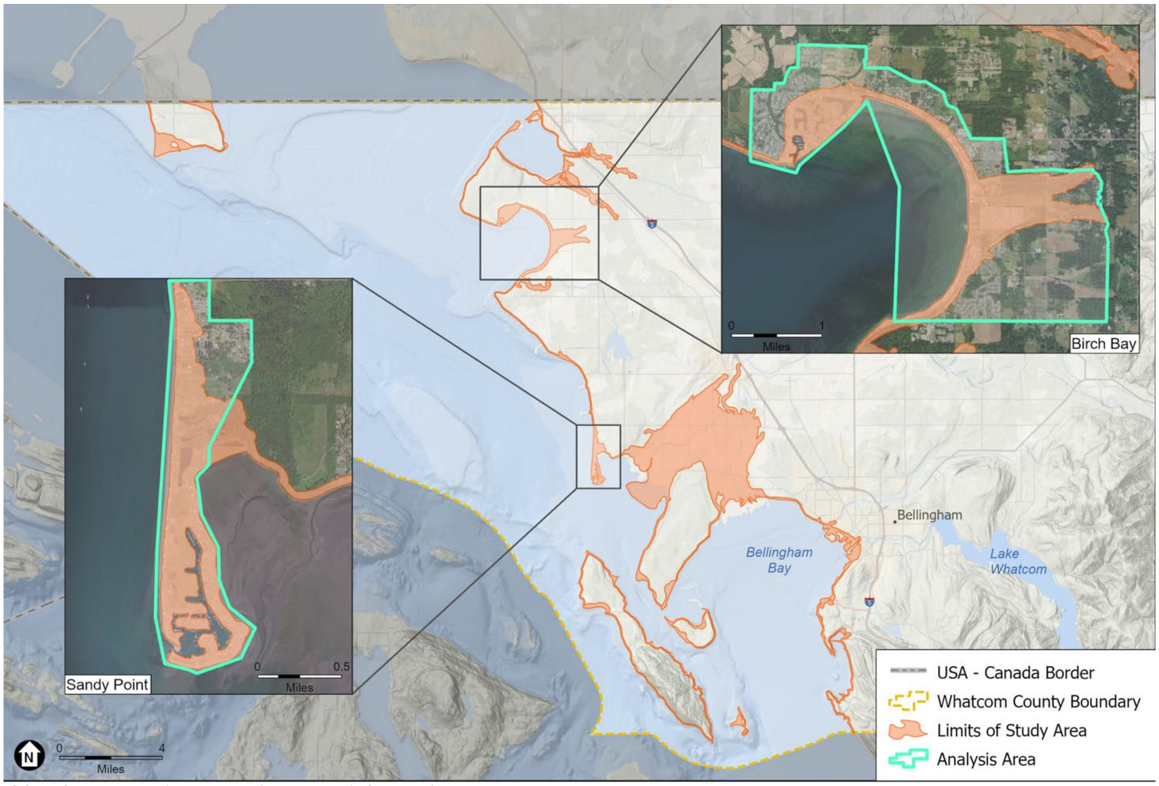
Sensitivity

- Degree to which a system is affected either adversely or beneficially by climate variability or change.

Adaptive Capacity

- Ability to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Vulnerability = (Exposure + Sensitivity) – Adaptive Capacity



SOURCE: Imagery (Maxar 2022); mapping (ESA 2023)

Whatcom County SLR Study

Figure ES-3
Birch Bay and Sandy Point

Results of County-Wide Exposure Analysis

Under current conditions, 133 buildings are at risk of inundation during king tides and 1,977 are at risk of flooding during the 100-year coastal event. In the short- and mid-term, the total number of buildings exposed to inundation during king tides increases to 487 and then 2,238. By the long-term with 6.6 feet of sea-level rise, 2,836 buildings are at risk of flooding during the 100-year event and 273 buildings are at risk of erosion by 2100.

Under current conditions, 4.1 miles of roadway are exposed to flooding during king tides and 30.6 miles are exposed during the 100-year coastal storm. With 3.3 feet of sea-level rise, this increases to 47.2 miles exposed annually. Haxton Way, which is the only ingress/egress to the Lummi Peninsula for the Lummi Nation and Whatcom County's Lummi Island Ferry, floods between Kwina Road and Slater Road during king tides under existing conditions, but less than 1-foot deep, so is likely still drivable. With 0.8 feet of sea-level rise, Slater Road west of Haxton Way begins to flood with king tides. With 3.3 feet of sea-level rise, both Slater Road and Haxton Way flood by more than 1 foot of water, restricting access for most vehicles. With 6.6 feet of sea-level rise, 77.3 miles of roads are exposed during the 100-year coastal storm.

Other results include:

- Other than the Sandy Point Fire Station #56, no hospitals, police stations, or fire stations are mapped in the hazard zones.
- No schools are mapped in the hazard zones.
- The Point Roberts Airpark is expected to be exposed to flooding during the 20-year coastal event with 3.3 feet of sea-level rise.
- The Ferndale Wastewater Treatment Plant is at risk of flooding during the 25-year riverine event with 0.8 feet of sea-level rise and the Bellingham Wastewater Treatment Plant is at risk of flooding during the 20-year coastal event with 3.3 feet of sea-level rise.
- Fairhaven Station in Bellingham (identified in the data as a landmark) is expected to be exposed to flooding during the 20-year coastal event with 3.3 feet of sea-level rise.
- The Visitors Information Center and Birch Bay Chamber of Commerce are at risk of flooding during king tides under 3.3 feet of sea-level rise.

Because the 100-year Nooksack River discharge event is expected to fill most of the river valley, sea-level rise and increased precipitation do not substantially increase the number of assets in the floodplain but would make extensive flooding more frequent and would increase the depth of floodwaters. As noted above, today's 100-year riverine flooding will occur approximately every 25 years by the end of the century and the current 25-year event will occur every 10 years by mid-century.

Results of Vulnerability Assessment

While the exposure analysis was conducted for the entire county, the vulnerability analysis focuses in more detail on two areas: Sandy Point and Birch Bay. These two areas were selected due to their existing exposure to regular flooding. Future efforts should consider extending the vulnerability assessment to include the entire coastline and lower Nooksack River.

While the vulnerability assessment considered all asset data that was available at the time of the study, the County focused on the publicly owned assets and other assets of importance to the public. The following are the assets most vulnerable to sea-level rise and erosion hazards in Sandy Point (i.e., received an overall vulnerability ranking of high or medium-high):

- **Fire Station:** The fire station floods under existing conditions during high tides with storm surge[4]. In Dec 2022-Jan 2023, the fire station was submerged under 4 feet of water and fire trucks were damaged (see Section 2.2.3). Flooding impacts the emergency response capabilities and response time for the Fire Department. The CoSMoS modeling shows that flood depths will continue to increase as sea levels rise.

[4] Storm surge is caused by elevated water levels due to large waves (from storms) that push water onshore. Storm surge may also arise from localized lower atmospheric pressure. The amount of surge, or abnormal rise in sea level during a storm, is dependent on the size, duration, and intensity of a storm as well as local factors such as coastal geomorphology and bathymetry, which may/may not block or redistribute storm surge to other more low-lying areas.

- **Sucia Drive and Saltspring Drive:** Under existing conditions, south Sucia Drive floods during king tides and storm events. With 0.8 ft of sea-level rise (2040-2060), most of Sucia Drive and Saltspring Drive are expected to flood south of Cleo Rose Lane during king tides without any storm surge, according to the CoSMoS results. With 3.3 ft of sea-level rise (2080-2100), these roads will be impassable during king tides. As the two main routes into and out of the peninsula, flooding of these roads will disrupt access pathways critical for emergency services as well as transportation links to local businesses, residences, and municipal infrastructure.
- **Natural Resources, such as kelp and eelgrass beds, beaches, wetlands, and Agate Lake:** In general, while beaches and wetlands are largely tolerant of fluctuating water levels, those that have been heavily degraded or modified may be less likely to cope with increased water depths and salinity. Some habitats may be able to shift inland or upland as sea level rises, particularly in areas where their migration is not blocked by shoreline armoring or coastal development (e.g., bulkheads, roads) (Krueger et al. 2011; Mauger et al. 2015). This is unlikely throughout the majority of Sandy Point given the presence of homes, structures, and roads along the coast that restrict the ability of habitats to shift inland.
- **Sandy Point Gardens:** This park area floods under existing conditions. Plants at the garden would likely be killed by saltwater inundation. Flooding would also cause loss of access to the recreational amenities.

The following are the assets most vulnerable to sea-level rise hazards in Birch Bay (i.e., received an overall vulnerability ranking of high or medium-high):

- **Birch Bay Drive:** Historically, this main thoroughfare has flooded 1-2 times per year during high tides with storm events: The frequency of flooding has likely been reduced along 1.5 miles of the shore following the Birch Bay Drive and Pedestrian Facility project construction completed in 2022[5], but the available coastal hazard mapping data do not account for the project effects. In 2018, Birch Bay Drive was one-way for almost a year after damage during king tides. The CoSMoS results show that with 0.8 ft of sea-level rise (2040-2060) about 30 feet of Birch Bay Drive in South Birch Bay would flood with water deeper than 1 foot during king tides (without any additional flooding from storm surge). By 3.3 ft of sea-level rise (2080-2100), all of Birch Bay Drive would be underwater during a king tide.
- **Bay Center Market:** As the main grocery store in Birch Bay, flooding of the Bay Center Market would reduce access to food without transportation. With 3.3 ft of sea-level rise (2080-2100), the CoSMoS results show that the market would flood during king tides (without any additional flooding from storm surge).
- **Sewer Lift Stations:** Flooding of sewer lift stations would likely impact the overall sewage system and could lead to impacts to the treatment system or overflows, which would impact water quality. Seven lift stations are expected to flood during king tides (without any additional flooding from storm surge) with 3.3 ft of sea-level rise (2080-2100), based on the CoSMoS results.
- **Natural Resources, such as kelp and eelgrass beds, beaches, wetlands, and freshwater ponds that provide critical habitat for fish, shellfish, and wildlife:** In general, while beaches and wetlands are largely tolerant of fluctuating water levels, those that have been

5 The flood reduction benefits of the Birch Bay Drive and Pedestrian Facility are not represented in the available flood maps and therefore not accounted for in this vulnerability assessment.

heavily degraded or modified may be less likely to cope with increased water depths. Some habitats (and tideland species such as shellfish) may be able to shift inland or upland as sea level rises, particularly in areas where their migration is not blocked by shoreline armoring or coastal development (e.g., bulkheads, roads) (Krueger et al. 2011; Mauger et al. 2015). This is unlikely in the majority of Birch Bay due to the presence of residential development and Birch Bay Drive. The southern area near Birch Bay State Park and Birch Bay Conservancy Area (adjacent to the southern border of the park) may be suitable for inland migration.

Potential Adaptation Strategies

Potential adaptation strategies were identified to reduce the County's vulnerability to impacts from sea-level rise and compound flooding (**Appendix E**). These approaches are generally described in state and federal guidance (see Section 6.1). In this study we take an initial look at which ones are appropriate for further consideration based on the conditions and vulnerabilities. Potential adaptation measures include:

- Protect – Soft Shore Techniques
  - Beach nourishment
  - Habitat restoration
  - Coastal bluff erosion best management practices
  - Large wood management
- Protect – Hard Defensive Structures
  - Beach retention structures (such as groins or breakwaters)
  - Strategic shoreline protection devices on a case-by-case basis
- Accommodate – Adapting in Place
  - Elevating or waterproofing structures and infrastructure
  - Elevating property grades
- Retreat
  - Relocate infrastructure through a deliberate and organized process (i.e., managed retreat)
  - Limit development in coastal hazard areas (e.g., update floodplain maps to replace 100-year with 500-year floodplain, zoning overlays, setback and buffer requirements, require sea level rise real estate disclosures)
  - Transfer development rights (e.g., buyouts, conservation easements, defeasible estates)

It is worth noting that this list is not exhaustive, and a detailed assessment of the costs, benefits, and detriments of different strategies has not been completed. Appendix E provides more details on each type of potential adaptation measure.

Recommended Next Steps

Additionally, this study includes an Action Plan with recommended tools, programs and policies, and funding sources that can help the County take action and implement adaptation strategies.

This study is intended to provide the basis for future adaptation planning. Based on the findings of the assessment, the following next steps are recommended:

1. Expand the Vulnerability Assessment:

   a. Extend the Vulnerability Assessment up the Nooksack River: The USGS Lower Nooksack River modeling focused on the compound impacts of sea-level rise and increased precipitation. Impacts due to sea-level rise only extend up to a certain portion of the river. As a result, the USGS focused on the lower Nooksack River from Ferndale to the mouth. A future study could assess the impacts of increased precipitation further up the river and evaluate the exposure, sensitivity, and adaptive capacity of assets in the floodplain to determine the County's vulnerability to riverine flooding with climate change.

   b. Extend the Vulnerability Assessment along the coastline (beyond just Sandy Point and Birch Bay): While the scope of this assessment focused on two specific areas to evaluate vulnerability, a future study could assess the impacts of sea-level rise along the full county coastline and evaluate the exposure, sensitivity, and adaptive capacity of assets in the floodplain.

   c. Conduct a detailed coastal change and erosion analysis and long-term monitoring program: Since CoSMoS does not include geomorphic responses and their influences on the spatial extent of flooding, a more detailed erosion analysis could be conducted to better understand how the shoreline may change in the future. Due to data limitations, the erosion hazard zone in this study should be considered a planning-level tool that provides the County with a high-level estimate of the potential scale of impact due to erosion. A more detailed analysis could include a delineation of the toe and top of bluffs and wetted beach from aerial imagery, evaluating historic shoreline positions to study past erosion, and conducting beach geomorphology analyses to understand how the beach would change with sea-level rise. The results of this analysis could also be used to adjust the flood extent in the hazard zone based on the predicted future geomorphology.

   d. Conduct habitat evolution/migration modeling: While some habitat data were available for this study, the exposure analysis was focused on risks due to inundation and erosion which are often natural and necessary processes for intertidal and subtidal habitats. Habitat evolution modeling[6,7] (e.g., how habitats are expected to move upslope with increasing sea levels based on inundation frequency and salinity exposure) can be used to better understand how coastal habitats will be impacted with sea-level rise (ESA 2015, ESA 2018). This type of modeling could help identify areas to preserve for future restoration and areas most at risk of being submerged under future climate conditions.

2. Develop a full Adaptation Plan: Through a public outreach process and in coordination with project partners, the County could develop preferred adaptation scenarios for different areas of the county, such as Sandy Point or along the Nooksack River, as part of an Adaptation Plan. A preferred scenario would likely be a combination of the adaptation strategies identified in Appendix E that would be implemented based on monitored triggers (e.g., a

[6] https://www.delmar.ca.us/DocumentCenter/View/4314/Final-Summary_Wetland-Habitat-Migration-Assessment_8162018

[7] See Appendix K (page 172) http://www.lospenasquitos.org/wp-content/uploads/2020/09/ESA-FINAL-Los-Penasquitos-Lagoon-Enhancement-Plan-APPENDICES.pdf

certain amount of sea-level rise, flooding more frequent than every year, a certain amount of bluff-top erosion). The plan could include a cost-benefit analysis to understand the tradeoffs of implementing expensive adaptation measures versus the damage that could be caused by flooding and erosion. The plan should also include identification of monitoring priorities (e.g., high water marks during flood events, water level data from gage network, sea level trends, the best available science) and adaptation triggers. Lastly, the plan could include potential policy language that could be incorporated into the plans listed in #3 below. Since planning documents are updated on specific timelines, developing policy language as part of an Adaptation Plan would provide the County with text specific to reducing compound flood risks due to climate change that could easily be added to each plan as it is updated (even if that is several years in the future). More and more resiliency funding is becoming available through federal and state grants and is often focused on multi-jurisdictional teams, similar to the one the County has developed for this project. The County should continue to work with project partners to develop proof-of-concept adaptation strategies.

a. Monitor erosion: Working with regional partners and research institutes, the County could support development of an erosion monitoring program in Puget Sound. For example, the County could work with Ecology to expand the monitoring that was done at Point Roberts and Point Whitehorn (Weiner et al. 2018). Alternatively, the County could identify new bluff top locations and beach cross-sections to regularly monitor for erosion. This data could be used to track high-erosion-risk areas and potentially refine the erosion hazard zone in the future.

b. Develop a coastal armoring geodatabase: Working with regional partners and research institutes, the County could support expanding Ecology's Coastal Atlas[8] coastal armoring data for Puget Sound. Information about the location, extent, and type of shoreline armor is a key piece of information when considering erosion and flooding because armored shorelines can reduce natural erosion from occurring and may cause exacerbated flooding or erosion for adjacent areas and can severely degrade coastal habitats such as forage fish spawning areas Since armoring is a potential adaptation strategy that landowners may pursue, gathering existing data can be helpful to inform a County-wide Adaptation Plan and potential suitability of armoring versus other alternatives at a site. Ecology has started this work, developing an armored shoreline inventory that includes Point Roberts and Point Whitehorn within Whatcom County (Weiner et al. 2018).

3. Implement adaptation strategies through local planning documents:

   a. Update the Shoreline Master Program (SMP) (WCC Title 23 1976), zoning, land division, and critical areas codes: Update regulations to reflect the results of this study, incorporate adaptation planning, and minimize risk to public and private assets.

   b. Update the Hazard Mitigation Plan: Incorporate policy recommendations to meet new standards under FEMA Local Mitigation Planning Policy[9]..

   c. Incorporate results and recommendations into Comprehensive Plan Update: Update goals and policies to reflect the results of this study and incorporate adaptation planning.

[8] https://apps.ecology.wa.gov/coastalatlasmap
[9] https://www.fema.gov/sites/default/files/documents/fema_local-mitigation-planning-policy-guide_042022.pdf

d. Incorporate results and recommendations into coastal and riverine floodplain planning processes and plans.

1. INTRODUCTION

Coastal communities have long been exposed to coastal hazards such as flooding, tsunamis, waves, and erosion, among others. As the global climate continues to warm and sea levels rise, many of these hazards will be exacerbated, becoming both more frequent and more intense. Identifying, preparing for, and adapting to the threats posed by sea-level rise and increased rainfall, will be one of the defining challenges of the century.

Whatcom County's shorelines are acutely vulnerable to the combined impacts of riverine and coastal flooding driven by changing climatic conditions. This compound flooding places the County's residents, infrastructure, natural systems, and cultural heritage at risk. In order to preserve Whatcom County's shorelines, it is important for the community to plan now, in conjunction with other regional partners, to ensure a sustainable and resilient future.

The county contains numerous miles of low-lying shoreline and steep bluffs, with both urban and rural development, adjacent to a marine environment. The extent of the risk and potential damage to existing and future development that could be caused by sea-level rise is currently unknown. This study identifies areas of the County that may be most vulnerable to sea-level rise and climate change and identifies strategies that may be applicable for addressing these risks. As part of the study, the County held three public meetings to identify existing risks and community priorities. The recommendations included in this study are intended to be incorporated into the County's current and long-term planning efforts.

This vulnerability assessment is organized as follows:

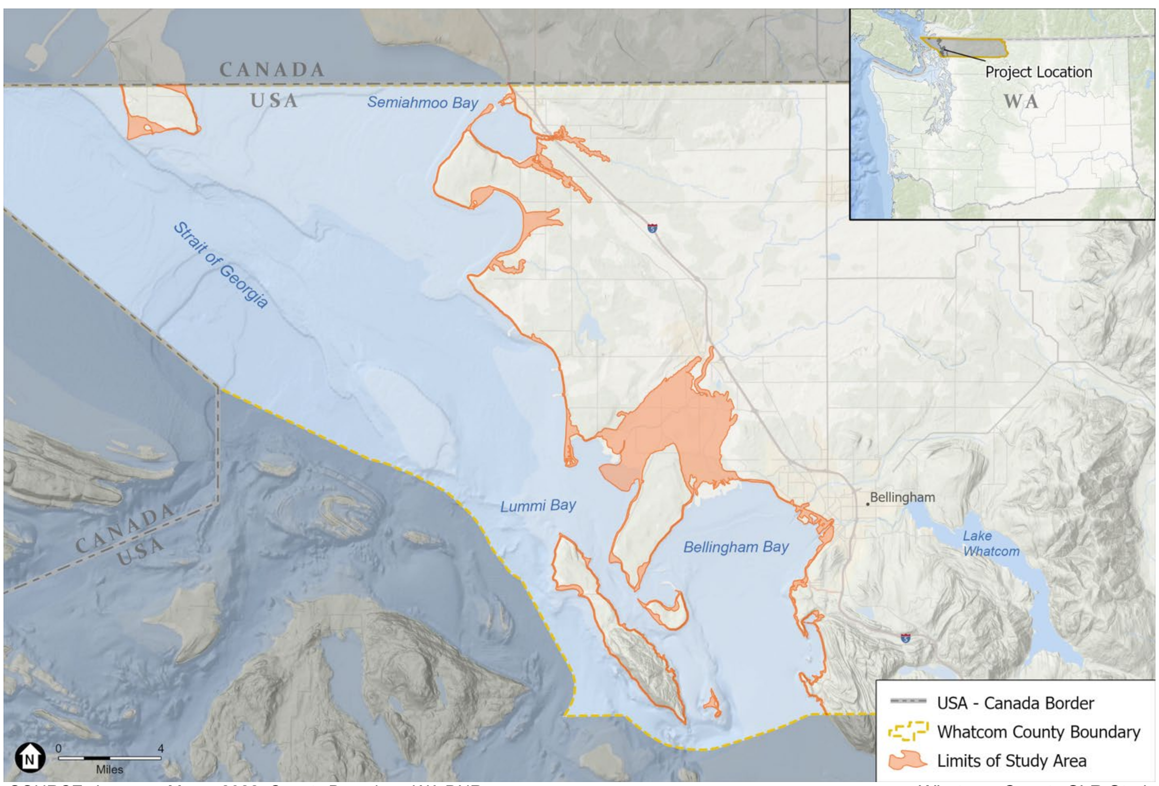
- Section 1: Introduction.
- Section 2: Existing Conditions, including definition of the project study area and a summary of existing coastal flooding, riverine flooding, and coastal sediment processes.
- Section 3: Data Collection and Processing, including regional climate change projections, an introduction to the flood modeling done by the U.S. Geological Survey (USGS), identification of the model scenarios chosen for Whatcom County, summaries of relevant existing studies, an asset inventory, and a summary of the community engagement completed to date.
- Section 4: Projected Hazard Zones, including identification of the different types of hazards considered in this study and development of hazard exposure maps for coastal flooding, riverine flooding, and erosion for entire coastal and lower Nooksack riverine shorelines.
- Section 5: Vulnerability Assessment, including an analysis of the exposure, sensitivity, and adaptive capacity of assets in Sandy Point and Birch Bay.
- Section 6: Action Plan, including existing adaptation policies and guidance as well as potential adaptation strategies and measures for Whatcom County.
- Section 7: Next Steps.

2. EXISTING CONDITIONS

This chapter describes the study area and physical processes relevant to Whatcom County's shorelines. This chapter also discusses the relevant planning context for future coastal hazard management.

2.1 Project Study Area

Bordered by the Canada-U.S. border to the north, Whatcom County extends from the Strait of Georgia and Bellingham Bay in the west to approximately 100 miles east to Okanogan County. Whatcom County is approximately 25 miles long from north to south and borders Skagit County and British Columbia. **Figure 2-1** below illustrates the County boundaries as well as the limits of the study area, which were developed based on the areas within the County's SMP (WCC Title 23 1976) as well as the extent of the available hazard mapping.



SOURCE: Imagery: Maxar 2022; County Boundary: WA DNR 2022; ESA 2023.

Whatcom County SLR Study

Figure 2-1
Project Area

Permitted shoreline uses and development in Washington State are guided by the state's Shoreline Management Act and individual city and county Shoreline Master Programs (SMPs). SMPs are local policies and regulations that account for varying public and private uses of marine and freshwater shorelines related to public access, natural resources, public and private development, and water-dependent uses (e.g., piers, marinas, ferry terminals). The primary focus of this study includes the marine shorelines defined by Whatcom County's SMP (WCC Title 23 1976) and the lower Nooksack riverine shorelines downstream of Ferndale/Slater Road Bridge, as well as the areas within 200 feet of the most extreme sea-level rise scenario determined by Mauger et al. (2015) (100-year flood event with 6.6 feet of sea-level rise) considered in this study.

2.2 Coastal Flooding Processes and Historic Events

2.2.1 Tidal Datums and Sea Level Trends

Whatcom County experiences mixed semidiurnal tides, or two daily high tides and two daily low tides of differing elevations. These daily tides also vary with the spring-neap tidal cycles, which occur approximately twice a month, as well as king tides, which are exaggerated tides that occur several times per year during the perigean spring tide (i.e., when the moon is the closest to the earth and the sun, moon, and earth are in alignment).[10] King tides cause exceptionally high and low tides, are already causing flooding throughout the County, and may exacerbate flooding when they occur simultaneously with low pressure storm systems. **Table 2-1** presents the tidal datums for the NOAA Cherry Point tide gauge.

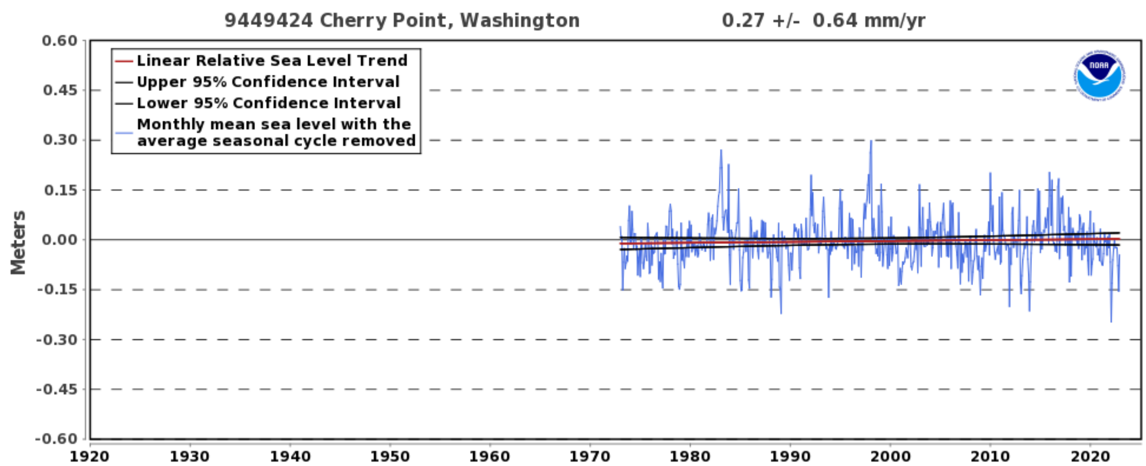
TABLE 2-1. TIDAL DATUMS AT CHERRY POINT (#9449424)

Tidal datum	Abbreviation	ft MLLW	ft NAVD
Highest Observed Tide		12.8	11.8
Highest Astronomical Tide	HAT	11.0	9.9
Mean Higher High Water	MHHW	9.2	8.1
Mean High Water	MHW	8.3	7.3
Mean Tide Level	MTL	5.5	4.4
Mean Sea Level	MSL	5.3	4.3
Mean Low Water	MLW	2.6	1.6
North American Vertical Datum of 1988	NAVD	1.0	0.0
Mean Lower Low Water (MLLW)	MLLW	0.0	-1.0
Lowest Astronomical Tide	LAT	-3.9	-4.9
Lowest Observed Tide	LOT	-4.3	-5.3

NOTES:
The tidal datums listed above are from the most recent tidal epoch: 1983-2001. Datums were converted from the tide gauge standard to NAVD using NOAA's online Vertical Datum Transformation Tool[11].
SOURCE: NOAA 2011

The Cherry Point tide gauge has been recording water level data since 1973. The relative sea level trend recorded over this period is 0.27 mm/yr, or 0.01 in/yr (i.e., 0.5 inches between 1973 and 2021). (**Figure 2-2**). Note, future sea-level rise is expected to accelerate (Miller et al. 2018).

[10] https://wsg.washington.edu/community-outreach/hazard-resilience-and-climate-adaptation/king-tides/program/
[11] https://vdatum.noaa.gov/vdatumweb/



SOURCE: NOAA 2023

Whatcom County Vulnerability and Risk Assessment

Figure 2-2
Monthly Mean Sea Levels over time at Cherry Point

2.2.2 Coastal Extreme Event Flooding

The Federal Emergency Management Agency, or FEMA, creates maps, known as Flood Insurance Rate Maps (or FIRMs), that show areas of flood risk under current conditions (i.e., without sea-level rise). While the maps are meant to provide information for flood insurance needs and requirements, they also provide useful county-wide storm flooding information. The flood maps for Whatcom County were last updated in January of 2019.

The base flood elevation (BFE), or total water level, includes the stillwater elevation plus wave runup for the 100-year return period storm. A return period refers to the average amount of time between events, or the frequency at which a given event may occur (also known as a recurrence interval). For example, the 100-year storm modeled by FEMA refers to a storm with a 1 in 100 (or 1%) chance of occurring annually, and a ~ 67% chance of being exceeded once in 100 years. Total coastal water surface elevation along the Whatcom County coastline for a 100-year storm ranges from 12 to 29 feet NAVD88 (FEMA 2019).

Coulton et al. (2002) calculated return period tides and non-tidal residuals[12] for the Sandy Point area based on 29 years of water level observations between 1971 and 2000. This work was accomplished under contract with Whatcom County with funding from FEMA, to be used to develop the coastal flood maps. **Table 2-2** below summarizes the water level extreme value analysis from the study. Non-tidal residuals represent water levels that were not predicted to occur due to tides (e.g., storm surge). Higher residuals mean higher water levels, which allows for waves to continue to shoal (build) and travel closer to shore, causing additional damage.

[12] Non-Tidal Residual (NTR) is the difference between observed and predicted tides, which is caused by meteorological and climatic conditions (e.g., water levels in excess of the predicted tides due to storm surge, El Nino decadal patterns, etc.).

TABLE 2-2. EXTREME COASTAL WATER LEVEL ELEVATIONS AND RETURN PERIODS FOR SANDY POINT

Return Period	Still Water Elevation (ft, NAVD) [a]	Non-Tidal Residual (ft) [b]
2-year	10.7	2.1
5-year	11.0	2.4
10-year	11.3	2.5
25-year	11.6	2.8
50-year	11.8	3.0
100-year	12.1	3.1

NOTES:
a Stillwater elevations were converted from NGVD29 (National Geodetic Vertical Datum of 1929) to NAVD using NOAA's Online Vertical Datum Transformation Tool and the longitude/latitude for the Cherry Point tidal gauge station.
b Values have been rounded to the nearest tenth.

2.2.3 Historic Coastal Flood Events

Historically, Whatcom County has experienced numerous coastal flood events.

Sandy Point

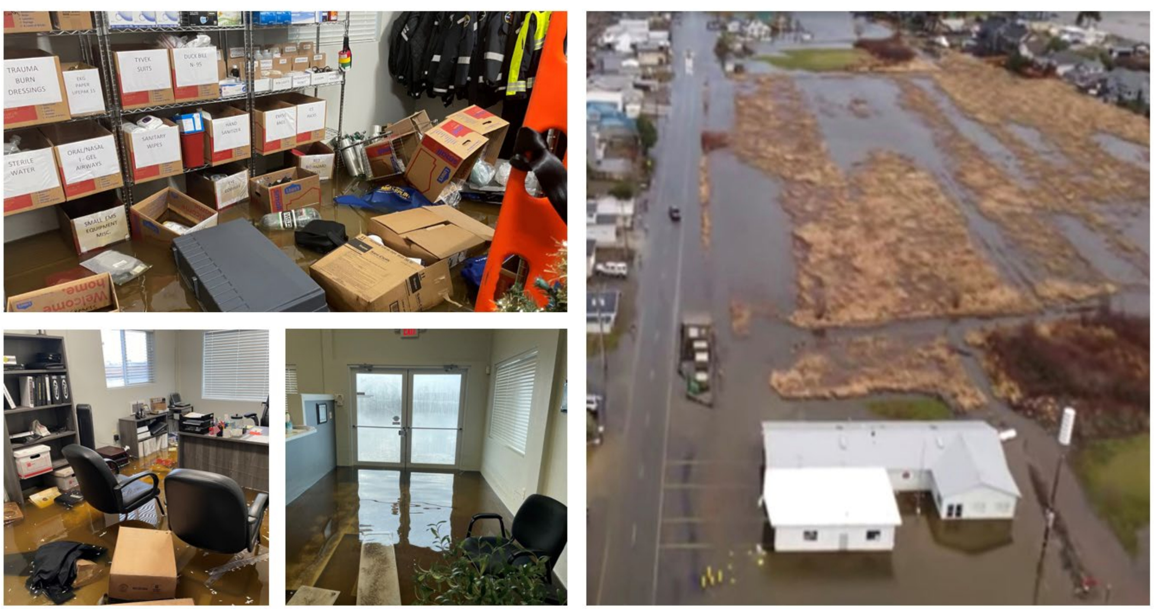
On December 15, 2000, a coastal flood event, estimated at a 20-year return period (or 5% annual chance of occurrence), occurred at Sandy Point. Flooding was caused by strong northwest winds occurring during a high astronomical tide with onlookers reporting wave heights between 10 and 20 feet. The flood event damaged approximately 60 homes and included bulkhead damage, broken windows, and damage from drift logs (Coulton et. al., 2002). Residents reported the damage was slightly worse than the damage from the coastal floods of March 1975 and December 1982 (Coulton et. al., 2002). **Figure 2-3** shows a photo of wave overtopping that occurred during this event.

Most recently in January 2022 and January 7, 2023, Sandy Point experienced severe flooding during king tides that submerged areas of Sandy Point under 4+ feet of water for multiple days. Numerous homes were damaged, and the Sandy Point Fire Station was flooded (**Figure 2-4**). Unlike past flooding events where flood waters naturally receded at low tide, the flooded areas during these two storms had to be manually pumped. The event resulted in over $1 million in damage to public and private assets (communication with John Gargett, Whatcom County Sheriff's Office, Division of Emergency Management).

SOURCE: Coulton et. al. 2002

Whatcom County SLR Study

Figure 2-3
Wave Overtopping Along Sandy Point During December 2000 Storm



SOURCE: John Gargett (County), 2023

Whatcom County SLR Study

Figure 2-4
Sandy Point Fire Department Station #56 During December 2022 and January 2023 Storms

Birch Bay

In 2002, Philip Williams & Associates (PWA; now Environmental Science Associates (ESA)) sent a questionnaire on coastal flooding to over 3,300 residents within the Birch Bay area. The questionnaire was prepared to solicit responses related to extreme tide elevation, wave runup, wave overtopping, and inland flooding observed by residents during past flood events. PWA verified water level measurements and predicted tide data at the Cherry Point tide gage for the time periods of the historic flood events mentioned on the questionnaires and developed **Table 2-3**.

In 2018, road damage resulting from coastal flooding produced by storm surge during a king tide closed Birch Bay Drive to one-way traffic for almost a year and caused approximately $3 million in road and structure damage (communication with John Gargett, Whatcom County Sheriff's Office, Division of Emergency Management).

TABLE 2-3. WATER LEVEL DATA FOR HISTORICAL FLOOD EVENTS IN BIRCH BAY

Date	Time	Stillwater Level (tide + wind setup) (ft MLLW)
December 1981	9:00 AM	-
December 16, 1984	12:00 PM	10.57
December 14, 1984	11:00 AM	11.82
November 28, 1996	8:00 AM	10.84
December 16, 1997	8:00 AM	12.64
December 15, 2000	-	11.48
December 14, 2001	6:00 AM	12.43

As a result of the historic, regular, and damaging flooding, the County designed and constructed the Birch Bay Drive and Pedestrian Facility "Berm" project, the largest coastal natural infrastructure project in the state. The gravel beach and cobble berm that was constructed as part of the project has reduced wave overtopping onto Birch Bay Drive and erosion in the project vicinity across its 1.5-mile span north of Terrell Creek. While the project reduces coastal erosion and flooding due to wave runup (ESA 2016), it does not reduce flooding of backshore areas due to rainfall and high tides and does not protect the entirety of the Birch Bay shore.

More recently, flooding occurred in January 2022 and January 2023 with the king tides. **Figures 2-5 and 2-6** show several photos of coastal flooding south of the Birch Bay Drive and Pedestrian Facility[13] project during the two king tide events. These photographs are of southern Birch Bay where homes are located bayward of Birch Bay Drive (Figure 2-5), and in a flood plain affected by rainfall runoff during high tides (Figure 2-6).

[13] The flooded areas are not protected by, nor affected by the Birch Bay Drive and Pedestrian Facility which is located farther north where there are no homes on the Bay side of the road. The flooded area is also proximate to Terrel Creek which runs parallel to shore, landward of the homes, before reaching the Birch Bay: Terrel Creek is another flood pathway for high Bay waters.

SOURCE: Teresa McKinnon

Whatcom County SLR Study

Figure 2-5
Flooding During January 2022 King Tide

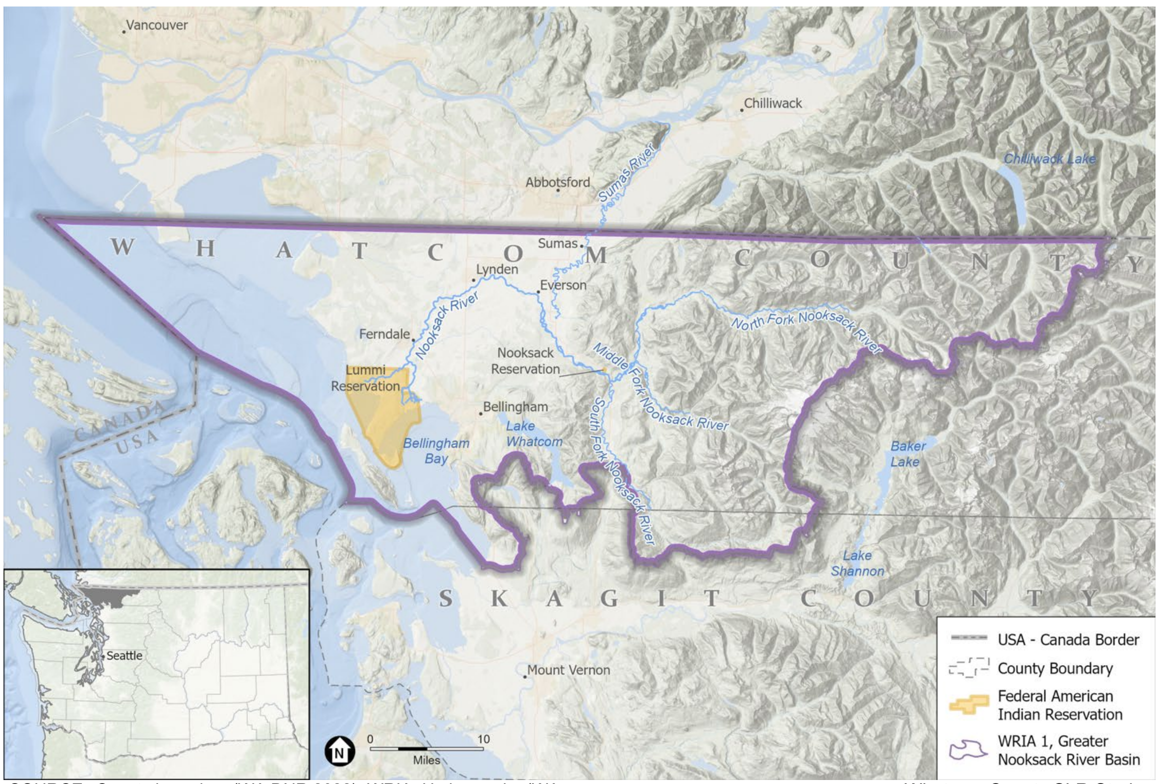
SOURCE: Teresa McKinnon

Whatcom County SLR Study

Figure 2-6
Flooding During January 2023 King Tide

2.3 Riverine Flooding

The Nooksack River is the largest river in Whatcom County. Its watershed encompasses much of the western portion of the county, exiting from the Cascade foothills and flowing northwestward between Stewart and Sumas Mountains, through the cities of Everson, Lynden, and Ferndale before reaching its delta in between Bellingham and the Lummi Reservation (see **Figure 2-7**). In the late 1800s, the Nooksack River, which historically shifted between what is now the Lummi River and the current Nooksack River alignment, was straightened and snagged for navigational purposes and levees were installed for flood control purposes; the latter partially disconnect the river from its floodplain depending on the size of the flood. The river carries a tremendous amount of sediment, building out the delta into Bellingham Bay and aggrading the channel, which reduces the slope upstream (NHC 2015). As a result, the conveyance efficiency through the delta has decreased, increasing overbank channel flow (NHC 2015).



SOURCE: County boundary (WA DNR 2022); WRIA, Hydrography (WA DOE 2023); Native American reservations (Esri 2023); mapping (ESA 2023)

Whatcom County SLR Study

Figure 2-7
Nooksack River Water Resource Inventory Area (WRIA) 1

2.3.1 Riverine Extreme Event Flooding

Similar to the coastal flood modeling, FEMA also models extreme event riverine flooding based on a range of storm return periods. The Flood Insurance Study (FIS) report (FEMA 2019) notes the drainage area and peak discharge for the Nooksack River as well as other creeks and tributaries throughout the County. A flood frequency analysis was conducted in 2005 to determine the return period events at Deming, Everson, and Ferndale. **Table 2-4** includes a summary of the riverine flooding discharge for the Nooksack River.

TABLE 2-4. SUMMARY OF DISCHARGES FOR THE NOOKSACK RIVER

	Peak Discharge (cfs)			
Flooding Source	**0.2% Annual Chance**	**1% Annual Chance**	**2% Annual Chance**	**10% Annual Chance**
Nooksack River- at Deming	94,861	74,497	66,394	48,634
Nooksack River- at Ferndale	69,998	60,502	56,723	39,599

SOURCE: Franz 2005

2.3.2 Historic Riverine Flood Events

The FEMA FIS report (2019) summarizes historic flooding for the Nooksack River. According to FEMA, the Nooksack has overflowed into the Sumas watershed since time immemorial with the first western documented overflow in 1893 and significant flood events in 1951, 1975, 1989, 1990, 1997, 1999, 2002, 2004, and 2009. The 1951, 1975, 1990, and 2009 (**Figure 2-8**) flood events are noted as the highest flows, estimated at a 36-year (2.8% annual chance of occurrence), 10-year (10% annual chance of occurrence), 13-year (7.7% annual chance of occurrence), and 25-year (4% annual chance of occurrence) return period, respectively (FEMA 2019, Grossman et. al. 2023). Damages from the November 1990 storm are estimated at $4 million for homes in Whatcom County and $24 million for public works infrastructure between Skagit, Snohomish, and Whatcom Counties (Hubbard 1994).

FEMA notes that damage to levees by erosion and overtopping is a significant problem and recurs during most large floods. Flooding along the Nooksack River frequently causes road closures along Slater Road and Marine Drive (both of which provide access to the Lummi Indian Reservation and Lummi Island, see **Figure 2-7**). Marine Drive was closed at least 17 times between 2007 and 2010 (FEMA 2019). Frequent road closures can have substantial impacts on the economic, public health, and safety of the affected areas.

Since the publication of the FEMA Flood Insurance Study, Whatcom County experienced extreme floods in February 2020 (the Super Bowl Flood; Figure 2-8) and back-to-back floods on the 14th and 28th of November 2021. While the February 2020 "Super Bowl" flood was large and overtopped the Nooksack River's north bank at Everson and caused flood damage northward to Sumas and into lower British Columbia, the subsequent November 2021 floods were declared a presidential major disaster in response to the November 13-15 flood event and resulting landslides. Damages in Whatcom County associated with the November 2021 floods are estimated at $150 million, with the displacement of thousands of families, damage to transportation infrastructure, and a tragic loss of life.[14][15] Damages in British Columbia were significantly higher.

SOURCE: USGS 2023

Whatcom County SLR Study

Figure 2-8
Photos of Nooksack River Flooding

2.4 Coastal Sediment Processes

Beach and bluff erosion can lead to flooding further inland and higher water levels with sea-level rise are expected to increase erosion rates. This section discusses the general sediment composition, modes of transport, and historic erosion along the coastline of Whatcom County.

2.4.1 Sediment Composition

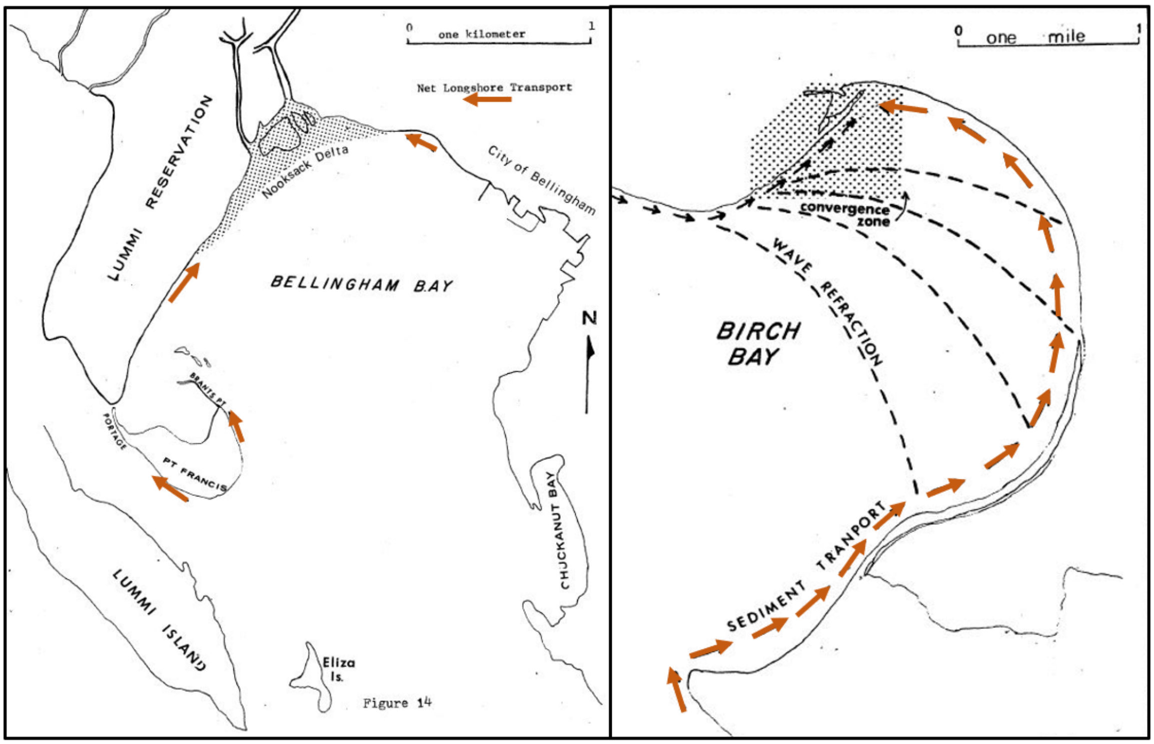
The rocky headlands, sand-gravel beaches, bluffs of coastal Whatcom County are composed of Glacial outwash of the Sumas State, Glaciomarine Drift of the Everson Interstade (sand and gravel, gravel and cobbles), and some Vashon Till (compact impermeable deposit of pebbles in a matrix of clay, silt, and sand) in the southern reaches of the County Deming sand, and Chuckanut Formation (late Cretaceous and early Tertiary arkoses, conglomerates, and siltstones) (Lapen 2000).

14 https://www.cascadiadaily.com/news/2022/nov/16/all-hell-broke-loose-one-year-post-flooding-in-whatcom-county/

15 https://www.whatcomcounty.us/4005/Emergency-Road-Repairs-Nov-2021-Flooding#:~:text=The%20historic%20floods%20in%20November,to%20roads%20damaged%20last%20November.

2.4.2 Sediment Transport

Whatcom County's shoreline is physically varied, consisting of high bluffs, low sandy beaches, deltas, and hard rock cliffs. The net direction of sediment transport ultimately depends on the dominant wave direction (e.g., predominantly southerly waves will move sediment northward, and predominantly northerly waves will move sediment southward); however, the local topography can also influence sediment transport. For example, as displayed in **Figure 2-9**, waves refract around local headlands and over bay depth contours, causing sediment transport around headlands.



SOURCE: Terich 1997, modified by ESA

Whatcom County SLR Study

Figure 2-9
Sediment Transport in Bellingham and Birch Bay

2.4.3 Historic Erosion

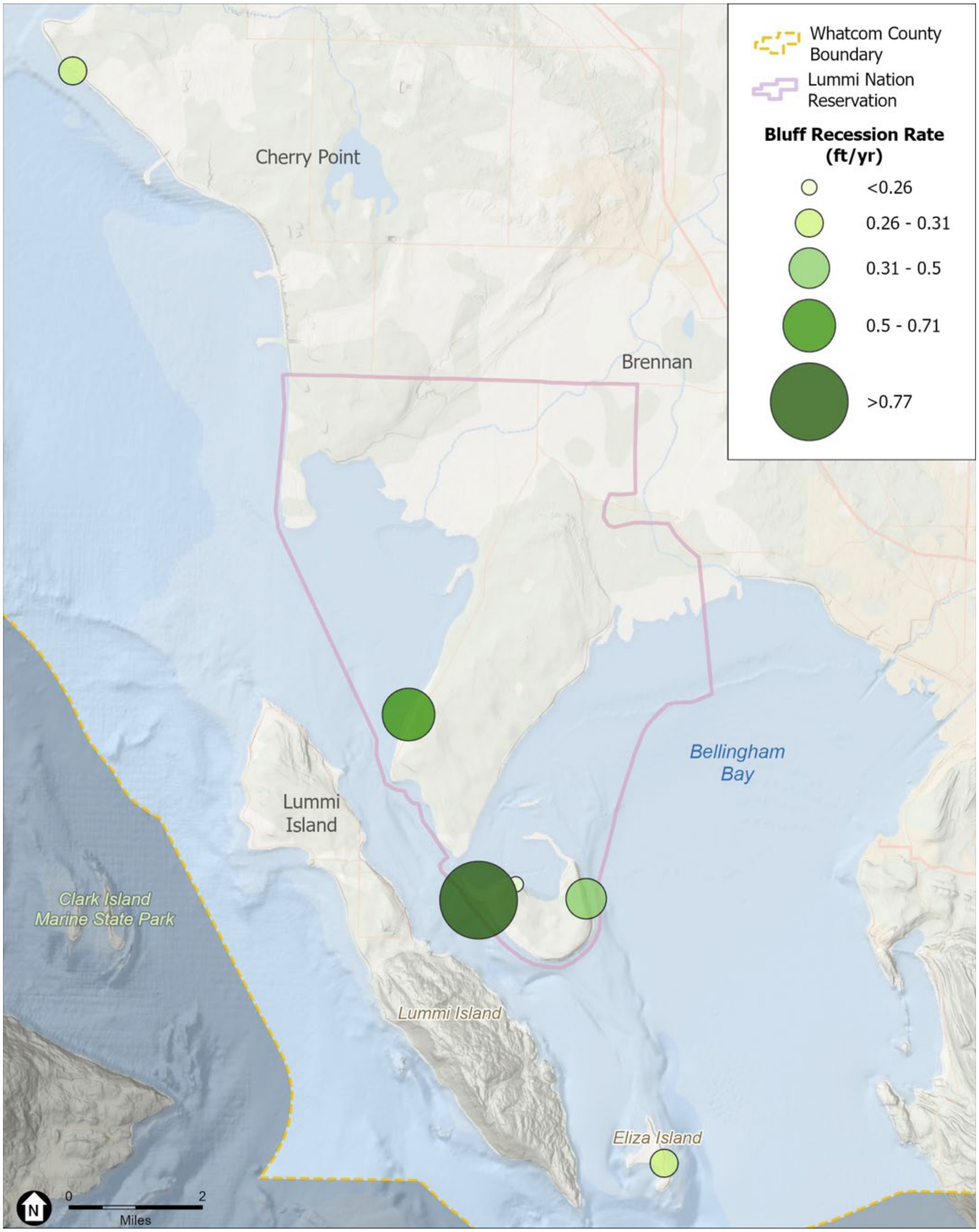
The erosion of coastal bluffs—high, steep landforms made of glacial and interglacial sediments—serves as the primary source of sediment for Puget Sound beaches (Johannessen and MacLennan 2007). Bluffs make up 42.6% of the Puget Sound shoreline (Coastal Geologic Services (CGS) 2018). Bluffs are dynamic features that may erode slowly over time or in large chunks over the span of several months to years. With higher sea-levels, erosion rates and extent are expected to increase.

Historical bluff recession rates in Whatcom County were measured at various locations by Coastal Geologic Services and are shown in **Figure 2-10**. CGS estimated historic bluff recession rates for three main categories of bluff shoretypes:

- **Feeder Bluffs (0.48 feet per year (ft/yr)):** bluffs that experience significant erosion and contribute sand and gravel to local beaches, although not as significant as the “exceptional” category. These bluffs vary greatly in height and the character of erosion, depending on local geologic factors. Evidence for feeder bluffs generally consists of active erosion, fallen trees, and indications of recent landslides. The Feeder Bluff Talus category, rocky bluffs that erode slowly and only occur on the southwest shores of Lummi Island within Whatcom County, were also included here.
- **Feeder Bluff Exceptional (0.68 ft/yr):** bluffs that are among the most rapidly eroding shorelines on Puget Sound and deliver large volumes of sediment to the beach. Exceptional feeder bluffs typically consist of abundant and easily erodible sand and gravel. Evidence for these bluffs includes active erosion and landslides. Eroded material (colluvium) is often found at the base of the slope and vegetation on the face of the bluff is unusual.
- **Transport Zones (0.31 ft/yr):** beaches backed by relatively stable bluffs with little active erosion. These segments do not contribute appreciable amounts of sediment to the littoral system and might be thought of as “neutral” or “non-contributing” bluffs. Transport zones lack typical indicators of erosion such as toe erosion and active landslides. Slopes often support conifers and other established vegetation communities.

Maps of the bluff shoretypes can be viewed on Whatcom County’s Compound Flood Viewer[16]. Beach erosion data for the County were not available.

[16] https://www.arcgis.com/apps/instant/sidebar/index.html?appid=656f1dc771504a71acf0532053b72835



SOURCE: Bluff recession (CGS 2018); mapping (ESA 2023)

Whatcom County SLR Study

Figure 2-10
Available Historic Bluff Recession Rates within Whatcom County

3. DATA COLLECTION AND PROCESSING

ESA collected publicly available data on physical processes impacting coastal and riverine flooding (e.g., sea-level rise, erosion), as well as data on assets (i.e., natural or built resources) in Whatcom County.

3.1 Regional Climate Change Projections

3.1.1 Regional Sea-Level Rise Projections

In 2018, as part of the Washington Coastal Resilience Project (WRCP), partners prepared an assessment of projected sea-level rise for Washington State (Miller et al. 2018) as an update to the National Research Council's previous assessment (NRC 2012). The study included projections for sea-level rise at various locations along the Pacific coast and the Puget Sound shoreline. The University of Washington's Climate Impacts Group (UW CIG) developed a website[17] that includes interactive sea-level rise data visualizations (e.g., **Figure 3-1**). The website presents different sea-level rise values based on two global greenhouse gas emissions scenarios:

High Emissions Scenario (Representative Concentration Pathway [RCP] 8.5) – This scenario represents "business as usual" and assumes a future where there are no significant local or global efforts to limit or reduce greenhouse gas emissions. This scenario assumes "high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long-term to high energy demand and greenhouse gas emissions."[18]

Low Emissions Scenario (RCP 4.5) – This scenario assumes more aggressive emissions reduction actions in which greenhouse gas emissions stabilize by mid-century and begin to decrease later in the century.

The 2018 assessment also provides a range of probabilities that were specifically included to inform decision-makers. The probabilities range from "extreme low" (0.1%) to "high" (>83%) and correspond to the likelihood that a given amount of sea-level rise will be exceeded. For example, the "extreme low" probabilistic projections correspond to a 0.1% chance of exceedance (i.e., 99.9% of models predict a lower amount of sea-level rise).

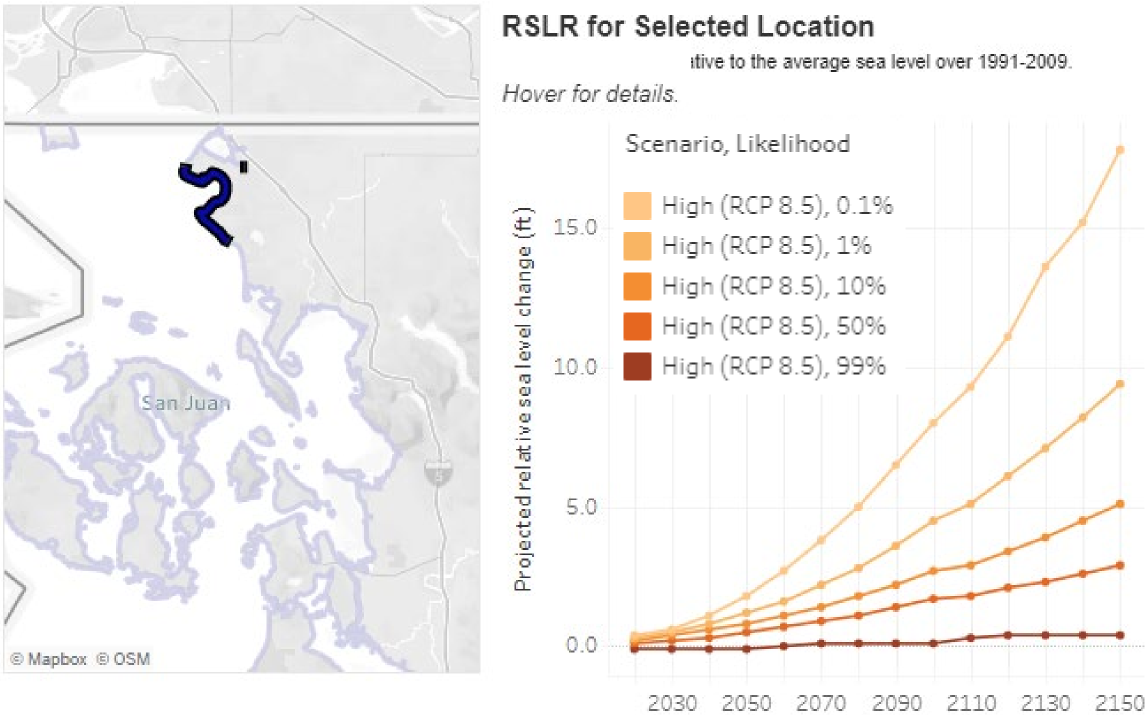
While Miller et al. (2018) study provides projections through 2150, it is important to note that sea-level rise is expected to continue for centuries, because the earth's climate, cryosphere[19], and

17 UW CIG. https://cig.uw.edu/resources/special-reports/sea-level-rise-in-washington-state-a-2018-assessment/

18 Riahi, K., Rao, S., Krey, V. et al., 2011. RCP 8.5 – A scenario of comparatively high greenhouse gas emissions. Climate Change 109, 33. https://doi.org/10.1007/s10584-011-0149-y https://link.springer.com/article/10.1007/s10584-011-0149-y#citeas

19 The cryosphere is the portion of the Earth's surface where water is in solid form, like glaciers and ice caps.

ocean systems will require time to respond to the emissions that have already been released to the atmosphere.



SOURCE: UW CIG, 2018

Whatcom County SLR Study

Figure 3-1
Example of Relative Sea-Level Rise Projections

3.1.2 Coastal Storm Changes

The effect climate change will have on extreme winds and waves is not as well defined as the effects on sea levels and precipitation intensity (Mauger et al. 2015). Hence, future conditions exposure mapping and associated vulnerability assessments and adaptation planning typically presume coastal water level and wave conditions will be similar to existing values, which are added directly to future water levels or propagated inland with additional hydrodynamic calculations.

3.1.3 Precipitation and Riverine Discharge Projections for the Lower Nooksack River

The UW CIG developed a report that summarizes projected climate change for the Puget Sound (Mauger et al. 2015). The report includes the following climate projections, relevant to Whatcom County and the Lower Nooksack River flooding[20]:

- Heavy rainfall is projected to be more frequent and intense. Twenty-four-hour rain events are projected to intensify by approximately 22% by the 2080s.
- More precipitation will fall as rain rather than snow, which will lead to higher winter streamflow (an increase of 28% - 34% on average by the 2080s).
- The timing of the Nooksack River's spring peak flow is predicted to occur an average of 27 days earlier, and the 100-year streamflow volume is predicted to increase by 27% by the 2080s.

More recent studies predict a more extreme increase in the 100-year streamflow volume, but those data were not final as of publishing of this report and will be included in future floodplain and climate planning efforts.

3.2 U.S. Geological Survey (USGS) Modeling

3.2.1 Coastal Storm Modeling System (CoSMoS)

The USGS's Coastal Storm Modeling System (CoSMoS) provides storm-induced coastal flood hazard mapping for current and future conditions. The USGS modeled wave generation and propagation in the Salish Sea as described in Crosby et al. (2023) and then applied the CoSMoS framework, which assesses regional water levels, waves, and compound flooding over large geographic areas and high resolution (1 meter), to Puget Sound (Nederhoff et al. 2022). The CoSMoS dataset has 50+ combinations of sea-level rise (e.g., 0 to 5 meters, or 0 to 16.4 feet, of sea-level rise) and storm scenarios (no storm, king tide, 1-year, 5-year, 10-year, 20-year, 50-year, and 100-year coastal events).[21] Whatcom County is one of the first areas in Puget Sound to be analyzed with the CoSMoS framework. The model results are preliminary and not yet publicly available, but results were provided to the County for the purposes of this study.

The hazard mapping does not include geomorphic responses and their influences on the spatial extent of hazards. For example, coastal erosion can result in a landward shift of flood extents, but mapping of this process requires additional analysis considering multiple parameters, which has not been accomplished. Anthropogenic (by people) changes that affect exposure to flooding may

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[20] Based on an analysis of 10 global climate model projections and the RCP 8.5 emissions scenario (Mauger et al. 2015.

[21] Note, the return period events in the model are based on current coastal storm return periods. Return periods are based on historic storm frequencies and indicate that such a storm is about 67% likely to occur or be exceeded at least once during the period. This analysis assumes that sea-level rise is linearly additive such that the X-year storm provides the same increase above the still water sea level whether under existing conditions or in the future. In reality, the recurrence of flood conditions may not be stationary, which means they may change with future climate changes or as our length of record increases and we observe more events.

or may not be included implicitly in the analysis, as these changes are typically small or just recently implemented and hence not resolved with regional mapping. For example, the Birch Bay Drive and Pedestrian Facility project completed in 2022 is not included in the topographic mapping used for the coastal flood mapping. Seawalls bulkheads and other coastal armoring have not been mapped or considered in this analysis.

3.2.2 Riverine Flooding Scenarios

The USGS recently completed a compound flood model for the Lower Nooksack River (from Ferndale to the river mouth) that considers higher downstream water levels combined with greater precipitation and discharge (Grossman et. al. 2023). A hydrodynamic model of the river was constructed and calibrated using data from a 2-year period and for two recent flood events (the January 2009 flood and the 2020 Super Bowl Flood). Once calibrated, the model was run for future scenarios using the results from CoSMoS as the downstream input for conditions with sea-level rise. Though the results are preliminary and not yet publicly available, the draft report was provided to the County for the purposes of this study. The model combines riverine flooding (existing, 1-year, 2-year, 10-year, and 25-year discharges) with sea-level rise (0 to 2 meters in 10-cm increments). The USGS also looked at increases in the discharge due to the increased precipitation projected under climate change (Section 3.1.2). They modeled the 10- and 25-year discharges adjusted for climate change with sea-level rise as shown in **Table 3-1**.

TABLE 3-1. LOWER NOOKSACK RIVER MODEL SCENARIOS

Time Period	Change Scenario	Sea-Level Rise Probability	Sea-Level Rise (ft)	Discharge Change
2040	Mean	50%	0.4 ft (0.15 m)	20%
2040	High	1%	0.9 ft (0.27 m)	32%
2080	Mean	50%	1.3 ft (0.40 m)	52%
2080	High	1%	3.1 ft (0.94m)	72%
SOURCE: USGS 2023				

3.3 Whatcom County Scenarios

For the purposes of this study, the County considered the high emissions scenario (RCP 8.5) to conservatively evaluate the vulnerability of County-wide assets under a high sea-level rise scenario. This scenario is conservative because it assumes emissions are not lowered in the future and will continue increasing. It is unlikely that emissions will exceed this scenario (Mauger et al. 2015). Current studies are showing emissions are tracking somewhere between RCP 4.5 and RCP 8.5 (McClure et al. 2022, Pedersen et al. 2020). The range of sea-level rise projections for the entire County is summarized in **Table 3-2** below.

TABLE 3-2. RANGE OF SEA-LEVEL RISE PROJECTIONS FOR WHATCOM COUNTY, WASHINGTON

	Miller et al. Sea-Level Rise Projections (ft)[1]		
Anticipated Timeline[1]	**10% Probability of Occurrence by this Date**	**1% Probability of Occurrence by this Date**	**0.1% Probability of Occurrence by this Date**
Now	0	0	0
2040	0.5 – 0.8	0.8 – 1.1	1.1 – 1.4
2080	1.8 – 2.2	2.8 – 3.2	5.0 – 5.4
2100	2.7 – 3.2	4.5 – 4.9	8.0 – 8.5

1. The range of projections is noted for the RCP 8.5, high emissions scenarios Source: UW CIG 2018,

The County selected 0.8 and 3.3 feet of sea-level rise to represent a short- and mid-term scenario based on the available CoSMoS results (Table 3-3). The County also chose to consider a more extreme scenario of 6.6 feet of sea-level rise. The short-term scenario has a 10% or less chance of occurring by 2030-2050. The mid-term scenario has a 10% or less chance of occurring by 2070-2120. The long-term scenario has a 1% or less chance of occurring by 2090-2120.

TABLE 3-3. MODELING SCENARIOS FOR WHATCOM COUNTY, WASHINGTON

UW CIG Projections			CoSMoS Scenarios		Lower Nooksack River Model Scenarios			FEMA FIRM
Anticipated Timeline	**Probability of Exceedance by this Date**		**Sea-Level Rise (ft)**	**Coastal Return Period**	**Sea-Level Rise (ft)**	**Riverine Return Period**	**Discharge Increase**	**Riverine Return Period**
Now	N/A	N/A	0	100-year	N/A	N/A	N/A	100-year
Short-term	10% or less by 2030-2050	50% by 2060	0.8	King Tide	0.9	N/A	N/A	N/A
				20-year	0.9	25-year	32%	N/A
Mid-term	10% or less by 2070-2120	50% by 2150	3.3	King Tide	3.1	N/A	N/A	N/A
				20-year	3.1	25-year	72%	N/A
Long-term	1% or less by 2090-2120	5% by 2150	6.6	100-year	N/A	N/A	N/A	N/A

Source: UW CIG 2018, USGS 2023, FEMA 2019

The amounts of sea-level rise modeled in the Lower Nooksack model do not align exactly with the CoSMoS scenarios (0.9 and 3.1 feet). The CoSMoS event scenarios also vary slightly from the Lower Nooksack model event scenarios. For example, the County chose the 100-year event with 6.6 feet of sea-level rise to evaluate an extreme scenario, but the corresponding 100-year event for the Lower Nooksack modeling was not available. Similarly, CoSMoS includes results for the 20-year event, but the Lower Nooksack model includes results for the 25-year event as extensive highwater mark data from a recent flood event of this approximate recurrence was available to calibrate the model. **Table 3-3** provides the combined CoSMoS and Lower Nooksack model scenarios used to develop the hazard maps for this study (see Section 4 for further details).

Because there is inherent uncertainty in both climate science and the sea-level rise projections, the selected sea-level rise amounts represent the “book ends”, or the lower and higher amounts of sea-level rise, that might be conservatively anticipated for Whatcom County over the next century. For example, while 0.8 feet of sea-level rise can be considered a short-term projection (10% chance of exceedance by 2040), it can also represent a highly likely amount of sea-level rise by 2100 (90-95% chance of exceedance by 2100) for the RCP 8.5 emissions scenario. In other words, by 2100, there is a 90-95% chance 0.8 feet of sea-level rise will be exceeded and only a 0.1-1% chance 6.6 feet will be exceeded. Using a range of sea-level rise estimates will support the County in evaluating the potential impacts and adaptation options as both the climate science and sea-level rise models continue to evolve.

3.4 Existing Studies

3.4.1 2022 Port of Bellingham Vulnerability Assessment

EA Engineering, Science, and Technology, Inc., PBC (EA) conducted a vulnerability assessment for the Port of Bellingham in 2022. The assessment considered various flooding scenarios using the results from CoSMoS (see **Table 3-4** below) to rank assets by vulnerability on a scale of “Low” to “High”. The study analyzed results for king tides and the 10-year, 50-year, and 100-year events. The results of the assessment showed that many Port assets, especially the most low-lying, are already at risk of flooding from king tides and intense precipitation events (i.e., stormwater flooding) and that this risk is expected to increase with climate change and sea-level rise.

TABLE 3-4. SEA-LEVEL RISE PROJECTIONS USED IN THE PORT OF BELLINGHAM VULNERABILITY ASSESSMENT

Sea-Level Rise (ft)
0
0.8
1.6
3.3

3.4.2 Prioritizing Sea-Level Rise Exposure and Habitat Sensitivity Across Puget Sound (CGS, 2022)

Coastal Geologic Services (CGS) and Washington Sea Grant prepared a report for the Puget Sound National Estuary Program in April 2022 that mapped sea-level rise vulnerability at the parcel scale across Puget Sound (CGS 2022). The study looked at the 20-year storm (5% chance of annual occurrence) under five sea-level rise scenarios, using sea-level rise projections from the University of Washington’s Climate Impacts Group (**Table 3-5**).

TABLE 3-5. SEA-LEVEL RISE PROJECTIONS USED IN CGS 2022

Anticipated Timeline	Likelihood (% Chance of Occurrence)
Now	n/a
2050	50%

2050	1%
2100	50%
2100	1%

NOTES:
The CGS study uses the RCP 8.5 (high) emissions scenario.
The amount of sea-level rise varies by shore reach so is not included here.

A range of scores for habitat sensitivity, infrastructure sensitivity, physical vulnerability, coastal erosion potential, and coastal flood exposure, among others was used to develop an overall vulnerability score.

One of the indices used was a Coastal Erosion Potential (CEP) score, which is used in Section 4.4 to develop the erosion hazard zone for this study. The CEP score was developed as a function of shore type (e.g., ranging from relatively stable (i.e., bedrock) to highly erodible (i.e., beaches and feeder bluffs) and wave height. The highest CEP scores resulted from the more erodible shore types with higher wave exposure. The study assigned a CEP score to each parcel along the coastline.

3.5 Asset Inventory

Information concerning critical assets in Whatcom County was obtained primarily from Coastal Geologic Services (CGS), Whatcom County, and the City of Bellingham. Available spatial data included the following:

- Parcels and buildings
  - Building footprints
  - Housing developments
  - Libraries
  - Parcels
  - Schools
- Communications facilities
  - Radio towers
  - Electric Power Facilities
- Emergency response assets
  - Fire hydrants
  - Fire stations
  - Police stations
  - Hospitals
- Natural resources
  - Freshwater ponds
  - Open channel creeks
- Land use assets
  - Agricultural crops
  - Forests
  - Landmarks
  - Restoration sites
- Transportation
  - Roads
  - Railroads
  - Airports
  - Marinas
  - Bus stations
- Sewer infrastructure assets
  - Lift stations
  - Manholes
  - Sewer mains and lines
  - Wastewater treatment plants
- Stormwater infrastructure assets
  - Catchbasins

  - Detention ponds
  - Open drains
  - Stormwater inlets
  - Stormwater lines
- Water infrastructure assets
  - Water distribution stations
  - Water main and lateral lines
- Recreation assets
  - Parks and trails

Data gaps include businesses (some data for Birch Bay was identified after the analysis was completed which could be included in a later phase), as well as intertidal and subtidal habitats. While habitat data was available in some cases, the exposure analysis is focused on risks due to inundation and erosion which are often natural and necessary processes for intertidal and subtidal habitats. Habitat migration modeling (i.e., how habitats are expected to move upslope with increasing sea levels) is not included in the scope of this study but is recommended as a next step (see Section 7).

3.6 Project Team

The County put together a broad team to review the development of this study. The Project Team included representatives from multiple departments and divisions within the County (watershed management, climate action, public works, emergency management, planning, river and flood, stormwater, health), USGS, Washington Sea Grant, Washington State Department of Ecology (Ecology), Port of Bellingham, Lummi Nation, and the Cities of Bellingham, Blaine, and Ferndale as well as consultants from ESA, CGS, and NHC. The Project Team met five times to inform development of the report and provided comments on the report.

3.7 Community Engagement

The County developed a Public Participation Plan to provide a road map to guide the County and consultant team in the engagement of community members and other stakeholders on this assessment and planning process. The plan identified who would be involved, why they should participate, how the feedback would be used, and participation opportunities. Fliers were developed for each workshop and meeting and sent to the project team for distribution through various County committee listservs, the Whatcom Watershed Information Network, and through Whatcom County Public Works outreach channels.

Two public workshops were held in person to gather input on existing flood hazards and community priorities. The first meeting was held on November 19, 2022, in Birch Bay and had approximately 40 attendees who were largely from the Birch Bay area. The second meeting was held on March 9, 2023, in Ferndale and had approximately 20 attendees with residents from Sandy Point, Birch Bay, Custer, Bellingham, and Ferndale. Community concerns and priorities can be summarized by the following topics:

- Damage to public infrastructure and private property:
  - Concerns over if and how stormwater infrastructure will adapt to rising sea-levels and increased precipitation when flooding from stormwater runoff is already an issue.

    - Funding for maintaining or improving existing infrastructure (e.g., flood gates, culverts, etc.).
    - Exacerbated runoff due to increased development and clear-cutting of forested areas.
    - Availability of flood insurance.
    - Insufficient limits on new development within floodplains (e.g., mitigation, avoidance, etc.).
- Effects on fish and wildlife habitat:
    - Saltwater intrusion.
    - Habitat connectivity.
    - Avian habitat.
- Risks to public health and safety:
    - Emergency preparedness before and access during and after extreme flood events.
    - Debris cleanup and damage (e.g., from boats not properly secured during events, logs, etc.).
    - Exceptionally vulnerable populations (e.g., senior citizens, underserved populations, etc.).
    - Impacts to the local economy:
    - Agriculture.
    - Tourism (housing and businesses).
    - Degradation of recreational resources.
    - Reduced beach access.
    - Lowered quality of natural ecosystems unable to adapt to rising seas.
    - Exacerbated impacts to sites that flood under existing conditions (e.g., Birch Bay Leisure Park).

A third public meeting was conducted virtually on June 14 to present the results of this study and was attended by 18 participants.

4. HAZARD ZONES

Future sea-level rise is expected to create a permanent rise in ocean water levels that would shift the water's edge landward and exacerbate existing flooding. Higher downstream water levels combined with more extreme rainfall events are expected to lead to more flooding along the Nooksack River. Higher sea levels will also increase erosion of beaches and bluffs and increase wave attack at the toe of coastal bluffs, resulting in narrower distances between assets and the water. Additionally, the combination of higher ocean water levels and erosion will mean that coastal storms will potentially cause greater flooding and damage, because a reduced beach width is less effective at reducing wave energy, and waves positioned at a higher elevation allow for a deeper reach landward.

4.1 Flood Hazard Zones

The first step in understanding Whatcom County's vulnerabilities to sea-level rise is identifying potential hazard areas using available regional tools. Existing and potential future coastal tidal inundation, coastal and riverine storm flooding, and erosion were mapped based on the results from the USGS's CoSMoS and Lower Nooksack River model and an assessment of erosion prepared by CGS and mapped by ESA.

Four potential hazard zones were mapped under the different sea level rise scenarios identified in Section 3.3:

- **King Tides**: areas where tidal inundation could be a regular event (1-2 times per year).
- **20-25-Year Flood Event:** areas that could flood during a 4-5% annual chance coastal or riverine storm event and experience wave impacts.
- **100-Year Flood Event:** areas that could flood during a 1% annual chance coastal or riverine storm event and experience wave impacts.
- **Erosion:** areas that are expected to erode due to increased water levels (i.e., beaches and the toes of coastal bluffs).

The king tides scenario was used to map areas where inundation is a regular event and to depict how frequent inundation could potentially change in the future with sea-level rise. The 100-year event was chosen to represent an extreme, and, therefore, more conservative scenario. The 20-25-year event was chosen as a more frequent storm event scenario.

The following sections describe how the different data sources were combined to develop the potential future hazard zones that result under the projected sea level scenarios. Maps of the potential future hazard zones for each sea-level rise scenario can be viewed on Whatcom County's Compound Flood Viewer[22].

4.2 Coastal Flooding with Sea-Level Rise

Coastal flooding results from the USGS CoSMoS model were used to develop the king tide hazard zone, the 20-25-year flood event hazard zone, and the 100-year flood event hazard zone. As discussed in Section 3.3, three sea-level rise scenarios were selected for Whatcom County: 0.8, 3.3, and 6.6 feet.

Additionally, FEMA flood mapping through the National Flood Insurance Program also provides coastal flooding extent and floodwater elevations for the 100-year event under current conditions, so the CoSMoS present day mean sea level scenario and current FEMA mapping were compared for more confidence in the results. FEMA does not model or map coastal storm events under varying levels of sea-level rise, so the CoSMoS results were used for future scenarios.

4.3 Riverine Flooding with Climate Change

Higher sea levels will exacerbate flooding in the lower portions of the creeks and rivers within Whatcom County, because higher ocean water levels will reduce drainage to the ocean, causing water to back up into nearshore rivers or creeks, as well as directly raising the elevation of the creek flood profile in the lower, coastal flood plain. CoSMoS flood mapping products include estimated riverine discharges given the atmospheric conditions driving coastal storms. This means that in the case of a 1% annual chance coastal storm event, CoSMoS results are not showing a 1% annual chance river flooding event, but rather a likely discharge during the modeled 1% annual chance coastal storm event.

To understand possible flooding along the Nooksack River during a more extreme river flooding event, the USGS's Lower Nooksack model was used. The "High" scenario (i.e., 0.9 feet of sea-level rise and higher discharge) was used for the 25-year discharge event for both 2040 and 2080 (see **Table 3-3** in Section 3.3).

NHC provided a review of the USGS Lower Nooksack River model based on their experience with hydraulic modeling on the Nooksack River. NHC noted that in a separate project with the County and the City of Ferndale modeling of the full Nooksack River basin showed that increased discharge due to climate change did not correspond with a 1 to 1 increase in discharge in the Lower Nooksack. This is due to the situation whereas flood events increase in size, the river overtops its north bank at Everson, referred to as the Everson Overflow, and sends a larger proportion of the flow northward where it ends up flowing to Canada and the Sumas Prairie. As a result, the USGS modeling is likely representing a conservatively high amount of flooding. However, the model does not yet account for flooding due to stormwater runoff nor groundwater levels that affect infiltration capacity, which may underestimate flooding.

22 https://www.arcgis.com/apps/instant/sidebar/index.html?appid=656f1dc771504a71acf0532053b72835

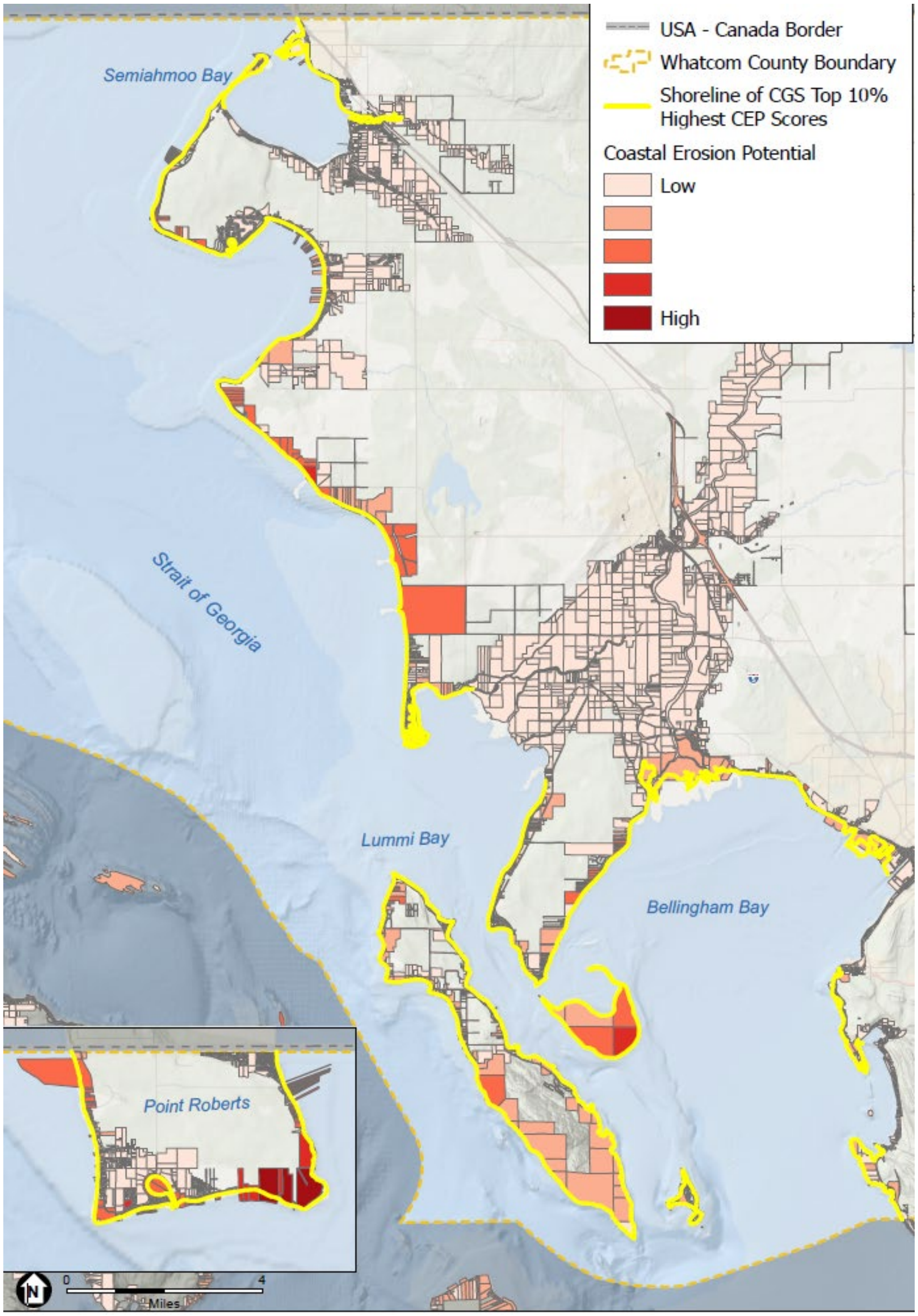
NHC found that the USGS's model appears to have good calibration in the mainstem channel and non-leveed areas, but was not propagating water to the Lummi River, west of the Lummi Nation, appropriately. The USGS model appears to be missing conveyance provided by ditches and culverts, and/or overstating topographic controls on flood waters. As a result, the USGS model may be underestimating the risk of flooding to Haxton Way, which is the only ingress/egress the Lummi Peninsula for the Lummi Nation and the Whatcom County's Lummi Island Ferry under most flood conditions.

4.4 Future Erosion with Sea-Level Rise

ESA used the CEP data from CGS 2022 (see Section 3.4.2) to identify the stretches of Whatcom County with the highest erosion potential based on shoretype and wind fetch distance (i.e., the length of water over which wind blows). In their study, CGS identified the top 10% of shorelines (beaches and bluffs) throughout the Sound with the highest CEP scores. These high-erosion-potential parcels from the CGS study were extracted for Whatcom County (**Figure 4-1**). The majority of the county shoreline is within the top 10% CEP scores in Puget Sound. The shoreline along these coastal parcels was then identified using the Washington State Water Body/Water Shoreline hydrography GIS layer as a starting point from which to model future erosion.

Future erosion was then projected inland for these parcels using conservative estimates based on available historic bluff erosion data along Puget Sound. CGS provided a review and summary of historic bluff erosion data, which showed a range of retreat rates (0.31 feet per year (ft/yr) for transport zones, 0.48 ft/yr for feeder bluff and feeder bluff talus, and 0.68 ft/yr for feeder bluff exceptional) (Appendix A). To simplify the analysis, ESA selected a rate higher than average historical erosion rates (0.48 ft/yr) to generally represent the increase in coastal erosion anticipated with accelerated sea level rise. A rate of 0.6 ft/yr was selected using engineering judgment and applied to all shores. While approximate, ESA's judgment is that an approximate erosion rate greater than historical erosion is preferred over explicitly or implicitly ignoring the potentially significant hazards associated with coastal erosion. The selected erosion rate was applied to the shorelines with the top 10% highest CEP scores.

Using this rate, a total amount of erosion was calculated for 2040, 2080, and 2100, estimated at 11 feet, 35 feet, and 47 feet respectively. For the identified erosive shoreline, an erosion zone was developed by buffering the existing shoreline inland by the amount of erosion for each scenario. Actual future erosion may exceed these amounts, which are not intended for uses other than a high-level risk assessment by the County. More detailed analysis is recommended for assets in close proximity to these erosion hazards.



SOURCE: Basemap: ESRI 2023; County Boundary: WA DNR 2022; Coastal Erosion Potential: CGS 2022; ESA 2023

Whatcom County SLR Study

Figure 4-1
Parcels with Highest Erosion Potential

It should be acknowledged that due to data limitations, the erosion hazard zone should be used as a planning-level tool to provide the County with a high-level estimate of the potential scale of impact due to erosion. Localized rates of erosion were not available and beach and bluff erosion rates typically differ from one another. Note that beach erosion data was not available, so the historic bluff erosion rates were applied to beaches as well in order to develop a rough estimate of potential erosion. Additionally, erosion rates are highly variable from one location to another and over time. Future efforts should consider development of a beach and bluff erosion monitoring program to better determine future erosion hazards. Additionally, sea-level rise is expected to increase erosion rates, however there is currently no modeling basis to estimate future physical rates of erosion in Puget Sound (CGS 2022). Future studies should refine estimates to consider how much rates will change. As a result, the erosion hazard zone should be considered a planning-level tool and should not be used for site-specific analyses.

4.5 Hazard Zone Maps and Exposure Analysis

A webmap of hazard zones may be found online on Whatcom County's Compound Flood Viewer[23]. The CoSMoS results show that the 20-year coastal storm event with 0.8 feet of sea-level rise floods an area similar to the 100-year coastal storm event today; with 3.3 feet of sea-level rise, king tides will flood an area greater than the 100-year coastal storm event today. The Lower Nooksack model results show that the 10-year discharge with 0.9 feet of sea-level rise floods an area similar to the 25-year discharge event today. Additionally, the 25-year discharge event with 3.3 feet of sea-level rise floods an area similar to the 100-year discharge event today. In other words:

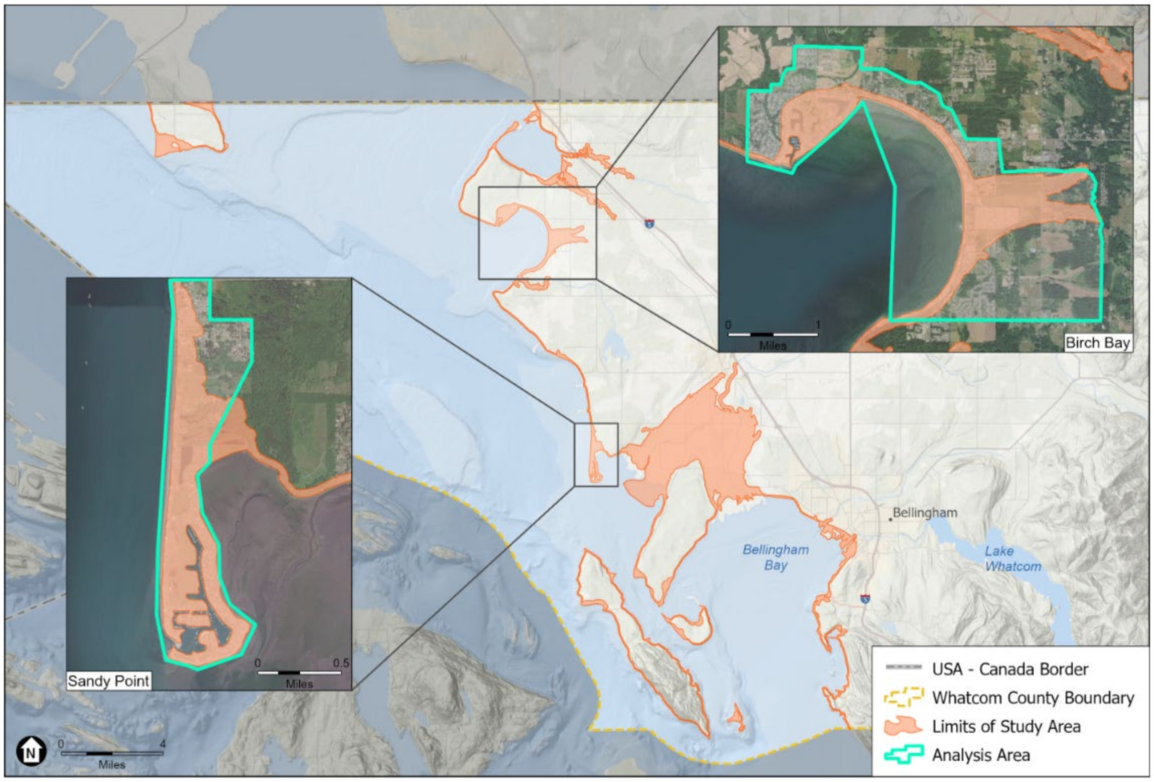
- Current 100-year coastal storm flooding (i.e., the FEMA FIRM flood extent) will occur approximately every 20 years by 2040-2060 (0.8 feet of sea-level rise) and every year by 2080-2100 (3.3 feet of sea-level rise).
- Current 25-year riverine flooding (like the 2009 flood) will occur approximately every 10 years by 2040-2060 (0.9 feet of sea-level rise).
- Current 100-year riverine flooding (i.e., the FEMA FIRM flood extent) will occur approximately every 25 years by 2080-2100 (3.1 feet of sea-level rise).

[23] https://www.arcgis.com/apps/instant/sidebar/index.html?appid=656f1dc771504a71acf0532053b72835

5. VULNERABILITY ASSESSMENT

This section uses the future hazard zones described in Section 4 to identify the assets potentially at risk from sea level rise and compound flood impacts (e.g., homes, roads, utilities). These places or assets, as described in Section 3, are categorized into the following asset categories: parcels and structures, infrastructure, natural resources, recreation, and communities. The vulnerability analysis focuses on two areas: Sandy Point and Birch Bay (**Figure 5-1**). These two areas were selected due to their existing exposure to regular flooding. It is important to note that Sandy Point is part of the Lummi Reservation, although many of the parcels are not owned by members of the Lummi Nation. As Federal policy has changed, and tribal lands have been allowed to be removed from trust to fee status, state and county regulations have become applicable. Representatives from the Lummi Nation participated in the project team meetings and approved selection of Sandy Point as one of the areas for the vulnerability analysis. It is the full intent of the County to continue working cooperatively with area tribes on compound flood adaptation planning (Whatcom County 2016).

In order to develop an Action Plan to address potential sea level rise and compound flood vulnerability, the risk of not taking action must be understood first. For this reason, the vulnerability assessment considers a “no action” scenario in which the County or other municipalities, private property owners, and managers do not respond to sea level rise. However, the County will review this assessment of vulnerability and determine the next best steps to improve resilience to the projected impacts.



SOURCE: Imagery: Maxar; ESA 2023

Whatcom County SLR Study

Figure 5-1
Birch Bay and Sandy Point

5.1 Vulnerability Assessment Approach

5.1.1 Exposure to Hazard and Consequences

To assess exposure to hazards, each potential future hazard zone was overlayed on the assets in different categories in GIS. Point assets (like police stations) in each potential future hazard zone were counted, linear assets (like roads and pipelines) were measured by mile, and planar assets (like agriculture land uses) were measured by acre. The full County-wide set of results is provided in tabular form in **Appendix B** and a summary of these results for Sandy Point and Birch Bay is reported in the second row of the tables in Appendix C and D.

In areas where flooding and erosion hazards overlapped, erosion was treated as the primary hazard because it was presumed that erosion generally causes more damage. For example, a house located close to the shoreline may be able to withstand occasional flooding, but the structural integrity would be threatened if the foundation has been eroded away.

It is important to note that the flooding and erosion hazard zones modeled in this study are not intended to provide site-specific analysis, but rather to provide a rough approximation of potential future risk to County assets so that the County may plan and prioritize adaptation actions.

To further characterize an asset's exposure to hazards, a *hazard exposure grade* of Low, Medium, or High was assigned. This grade was assigned after quantifying the asset's exposure, and is dependent on timeframe (e.g., if an asset could potentially flood in the near-term, i.e., over the next 20-30 years, with smaller amounts of sea-level rise) it would have a higher hazard exposure grade than an asset that could experience flood impacts under one of the more extreme scenarios) and the potential level of severity posed by the type of hazard zone (e.g., annual king tide flooding would have a higher hazard exposure grade than flooding during a 20-year event).

The hazard exposure grading scheme is provided in **Table 5-1**.

TABLE 5-1. HAZARD EXPOSURE GRADING

Timeframe/Sea-Level Rise Amount	King Tide Flooding	20-year Event Flooding	100-year Event Flooding	Erosion
Short-term/ 0.8 ft	High	Medium	n/a	High
Mid-term/ 3.3 ft	Medium	Low	n/a	High
Long-term/ 6.6 ft	n/a	n/a	Low	Medium

5.1.2 Sensitivity to Hazard

In the third row of each table, an asset's sensitivity, or the asset's level of impairment if flooded or affected by erosion or waves, is discussed. In general, assets that are highly sensitive would lose their primary function if exposed to any degree of flood or erosion whatsoever. If assets can maintain their primary function(s) during inundation, they would have low sensitivity. If assets would lose only part of their function, it is considered for the purposes of this assessment, moderately sensitive. For example, one of the sensitivities of impacts to roads is the disruption of vehicular access critical for the provision of emergency services, which would mean the asset has a high sensitivity.

Similar to the hazard exposure grades, a *sensitivity to hazard grade* is determined for each asset. **Table 5-2** presents the grading scheme.

TABLE 5-2. HAZARD SENSITIVITY GRADING

Considerations	Grade
The given hazard would have no or a low impact on the asset and the primary function of the asset could be maintained.	Low
The given hazard would cause minor damage or disruption.	Medium
The given hazard would cause major damage or disruption.	High

5.1.3 Adaptive Capacity of Asset

In the fourth row of each table, an asset's adaptive capacity, or the asset's ability to cope with and recover from impacts, is discussed. In general, assets that have low adaptive capacity are unable to recover quickly, or at all, if exposed to any degree of flood or erosion whatsoever. If assets are operational as soon as water recedes, they would have high adaptive capacity. For example, in many cases once waters recede off roads, vehicular access can be restored if little damage was sustained to the roadway itself, which would mean the asset has a high adaptive capacity to flooding. Note, adaptive capacity is inversely correlated with vulnerability (i.e., low adaptive capacity leads to higher vulnerability).

An *adaptive capacity grade* is determined for each asset. **Table 5-3** presents the grading scheme.

TABLE 5-3 ADAPTIVE CAPACITY GRADING

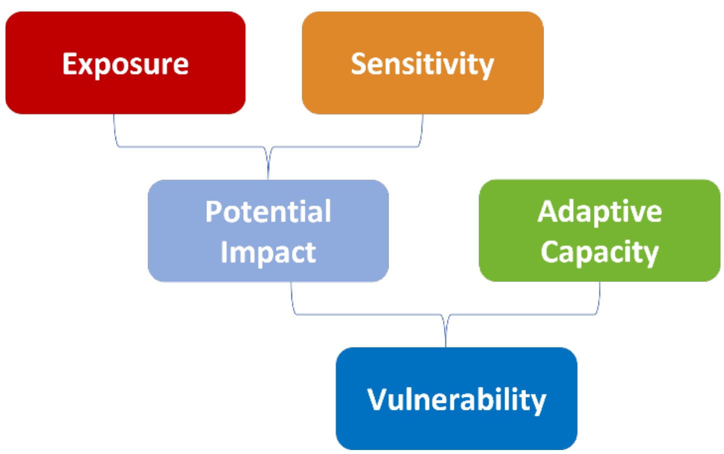
Considerations	Grade
The asset would be able to rebound from the impact quickly.	High
The given hazard would cause temporary operational interruption.	Medium
The given hazard would cause long-term operational interruption. The asset would require significant effort to rebound from the impact.	Low

5.1.4 Vulnerability Summary

The last row of each table identifies the overall vulnerability of the asset categories to potential future inundation and storm flooding, as determined by the analysis. The overall vulnerability is determined based on the combination of an asset's vulnerability components (**Figure 5-2**):

$$\textit{Vulnerability} = (\textit{Exposure} + \textit{Sensitivity}) - \textit{Adaptive Capacity}$$

The vulnerability summaries are indications of the degree of potential vulnerability, not rankings or priorities.



SOURCE: ESA

Whatcom County SLR Study

Figure 5-2
Components of Vulnerability

5.2 County-Wide Exposure

Appendix B provides the full County-wide set of results. Under current conditions, 133 buildings are at risk of inundation during king tides (59 of which are in either Birch Bay or Sandy Point) and 1,977 are at risk of flooding during the 100-year event. In the short- and mid-term, the total number of buildings exposed to inundation during king tides increases to 487 and then 2,238. By the long-term with 6.6 feet of sea-level rise, 2,836 buildings are at risk of flooding during the 100-year event and 273 buildings are at risk of erosion by 2100.

Under current conditions, 4.1 miles of roadway are exposed to flooding during king tides and 30.6 miles are exposed during the 100-year coastal storm. With 3.3 feet of sea-level rise, king tide exposure increases to 47.2 miles exposed annually. Haxton Way, which is the only ingress/egress to the Lummi Peninsula for the Lummi Nation and Whatcom County's Lummi Island Ferry, floods between Kwina Road and Slater Road during king tides under existing conditions, but less than 1-foot deep, so is likely still drivable. With 0.8 feet of sea-level rise, Slater Road west of Haxton Way begins to flood with king tides. With 3.3 feet of sea-level rise, both Slater Road and Haxton Way flood by more than 1 foot of water, restricting access for most vehicles. With 6.6 feet of sea-level rise, 77.3 miles of roads are exposed during the 100-year coastal storm.

Other results include:

- Other than the Sandy Point Fire Station #56, no hospitals, police stations, or fire stations are mapped in the hazard zones.
- No schools are mapped in the hazard zones.
- The Point Roberts Airpark is expected to be exposed to flooding during the 20-year coastal event with 3.3 feet of sea-level rise.
- The Ferndale Wastewater Treatment Plant is at risk of flooding during the 25-year riverine event with 0.8 feet of sea-level rise and the Bellingham Wastewater Treatment Plant is at risk of flooding during the 20-year coastal event with 3.3 feet of sea-level rise.
- Fairhaven Station in Bellingham (identified in the data as a landmark) is expected to be exposed to flooding during the 20-year coastal event with 3.3 feet of sea-level rise.
- The Visitors Information Center and Birch Bay Chamber of Commerce are at risk of flooding during king tides under 3.3 feet of sea-level rise.

Because the 100-year Nooksack River discharge event is expected to fill most of the river valley, sea-level rise and increased precipitation do not substantially increase the number of assets in the floodplain but would make extensive flooding more frequent and would increase the depth of floodwaters. As discussed in Section 4.5, today's 100-year riverine flooding will occur approximately every 25 years by the end of the century and the current 25-year event will occur every 10 years by mid-century.

5.3 Sandy Point Vulnerability Assessment

Appendix C provides the detailed vulnerability assessment for Sandy Point while Table 5-4 provides a summary of the results. Green cells refer to factors that contribute to lower vulnerability while red cells refer to high vulnerability. While the vulnerability assessment considered all asset data that was available at the time of the study, the County focused on the publicly owned assets and other assets of importance to the public. The following are the assets most vulnerable to sea-level rise and erosion hazards (i.e., received an overall vulnerability ranking of high or medium-high) in Sandy Point:

- **Fire Station:** The fire station floods under existing conditions during high tides + storm event. In Dec 2022-Jan 2023, the fire station was submerged under 4 feet of water and fire trucks were damaged (see Section 2.2.3). Flooding impacts the emergency response capabilities and response time for the Fire Department. The CoSMoS modeling shows that flood depths will continue to increase as sea-levels rise.
- **Sucia Drive and Saltspring Drive:** Under existing conditions, south Sucia Drive floods during king tides and storm events. With 0.8 ft of sea-level rise (2040-2060), most of Sucia Drive and Saltspring Drive are expected to flood south of Cleo Rose Lane during king tides without any wind waves, according to the CoSMoS model results. With 3.3 ft of sea-level rise (2080-2100), these roads will be undriveable during king tides. As the two main routes into and out of the peninsula, flooding of these roads will disrupt access pathways critical for emergency services as well as transportation links to local businesses, residences, and municipal infrastructure.
- **Natural Resources, such as kelp and eelgrass beds, beaches, wetlands, and Agate Lake:** In general, while beaches and wetlands are largely tolerant of fluctuating water levels, those that have been heavily degraded or modified may be less likely to cope with increased water depths. Some habitats may be able to shift inland or upland as sea level rises, particularly in areas where their migration is not blocked by shoreline armoring or coastal development (e.g., bulkheads, roads) (Krueger et al. 2011; Mauger et al. 2015). This is unlikely throughout the majority of Sandy Point given the presence of homes, structures, and roads along the coast that restrict the ability of habitats to shift inland.
- **Sandy Point Gardens:** This park area floods under existing conditions. Plants at the garden would likely be killed by saltwater inundation. Flooding would also cause loss of access to the recreational amenities.

TABLE 5-4. SANDY POINT VULNERABILITY ASSESSMENT SUMMARY

Asset Category	Asset	Potential Exposure to Hazard	Sensitivity to Hazard	Adaptive Capacity of Asset	Vulnerability
Structures	Fire Station	High	High	Medium	**High**
	Others (Homes/Businesses)	High (273)[1]	Medium	Medium	**High**
		Medium (271)		Low (South of Cleo Rose Ln)	**Medium-High**
		Medium (34)		High (North of Cleo Rose Ln)	**Medium-Low**
		Low (15)		Medium	**Medium-Low**
Stormwater Infrastructure	Inlets and Open Drains	Low to High	Medium	High	**Medium-Low**
Roads	Sucia Dr Saltspring Dr	High	High	High	**Medium-High**
	S Beach Wy	Low	High		**Medium-Low**
	Patos Rd Thetis Wy Mayne Ln Puffin Rd Matia Dr Stuart Cir	Medium	Medium		**Medium-Low**
	Cleo Rose Ln Tsata Ln Neptune Ln Germaine Rd Olympic Dr	Low	Medium		**Low**
Natural Resources	Kelp and eelgrass beds Beaches Wetlands Freshwater pond (Agate Lake)	Medium	High	Low	**Medium-High**
Recreation	Sandy Point Marina	Medium	Medium	Medium	**Medium**
	Parks Sandy Point Gardens	High	High	Medium	**Medium-High**
	Parks Sandy Point Swings Sandy Point Tennis Court		Low	High	**Medium-Low**

1. Number of exposed buildings

5.4 Birch Bay Vulnerability Assessment

Appendix D provides the detailed vulnerability assessment for Birch Bay while Table 5-5 provides a summary of the results. As in Table 5-4, green cells refer to factors that contribute to lower vulnerability while red cells refer to high vulnerability. While the vulnerability assessment considered all asset data that was available at the time of the study, the County focused on the publicly owned assets and other assets of importance to the public. The following are the assets most vulnerable to sea-level rise and erosion hazards (i.e., received an overall vulnerability ranking of high or medium-high):

- **Birch Bay Drive:** Historically, this main thoroughfare has flooded 1-2 times per year during high tides with storm events. The frequency of flooding has been reduced along 1.5 miles of the shore following the Birch Bay Drive and Pedestrian Facility project construction completed in 2022[24]. In 2018, Birch Bay Drive was one-way for almost a year after damage during king tides. The CoSMoS results show that with 0.8 ft of sea-level rise (2040-2060) about 30 feet of Birch Bay Drive in South Birch Bay would flood with water deeper than 1 foot during king tides (without any additional wind waves). By 3.3 ft of sea-level rise (2080-2100), all of Birch Bay Drive would be underwater during a king tide.
- **Bay Center Market:** As the main grocery store in Birch Bay, flooding of the Bay Center Market would reduce access to food without transportation. With 3.3 ft of sea-level rise (2080-2100), the CoSMoS results show that the market would flood during king tides.
- **Sewer Lift Stations:** Flooding of sewer lift stations would likely impact the overall sewage system and could lead to impacts to the treatment system or overflows, which would impact water quality. Seven lift stations are expected to flood during king tides with 3.3 ft of sea-level rise (2080-2100), based on the CoSMoS results.
- **Natural Resources, such as kelp and eelgrass beds, beaches, wetlands, and freshwater ponds:** In general, while beaches and wetlands are largely tolerant of fluctuating water levels, those that have been heavily degraded or modified may be less likely to cope with increased water depths. Some habitats may be able to shift inland or upland as sea level rises, particularly in areas where their migration is not blocked by shoreline armoring or coastal development (e.g., bulkheads, roads) (Krueger et al. 2011; Mauger et al. 2015). This is unlikely in the majority of Birch Bay due to the presence of residential development and Birch Bay Drive. The southern area near Birch Bay State Park and Birch Bay Conservancy Area may be suitable for inland migration.

TABLE 5-5. BIRCH BAY VULNERABILITY ASSESSMENT SUMMARY

Asset Category	Asset	Potential Exposure to Hazard	Sensitivity to Hazard	Adaptive Capacity of Asset	Vulnerability
Structures	Bay Center Market	Medium	High	Medium	**Medium-High**
	Visitor Accommodations	Medium	Medium	Medium	**Medium**
	Unanchored Homes (Edgewater Trailer Park)	Medium	High	Low	**Medium-High**
	Other (Homes/Businesses)	High (142)			**Medium-High**
		Medium (1,221)	Medium	Medium	**Medium**
		Low (75)			**Medium-Low**
Stormwater Infrastructure	Inlets and Catch Basins	Low to High	Medium	High	**Medium-Low**
	Manholes	Low to High	Medium	High	**Medium-Low**
Sewer Infrastructure	Lift Stations	Medium (7)	High	Low	**Medium-High**

24 The flood reduction benefits of the Birch Bay Drive and Pedestrian Facility are not represented in the available flood maps and therefore not accounted for in this vulnerability assessment.

<table>
<tr><th>Asset Category</th><th>Asset</th><th>Potential Exposure to Hazard</th><th>Sensitivity to Hazard</th><th>Adaptive Capacity of Asset</th><th>Vulnerability</th></tr>
<tr><td>Emergency Response Infrastructure</td><td>Fire Hydrants</td><td>Low to High</td><td>Medium</td><td>High</td><td>Medium-Low</td></tr>
<tr><td rowspan="4">Roads</td><td>Birch Bay Drive</td><td>High</td><td>High</td><td>High</td><td>Medium-High</td></tr>
<tr><td>Jackson Rd</td><td>High</td><td>Medium</td><td>High</td><td>Medium</td></tr>
<tr><td>Chehalis Rd
Chehalis Pl
Cowichan Rd
Sehome Rd
Sehome Ct
Nootka Loop
Birch Dr
Cotterill Blvd
Morrison Ave
Terrill Dr
Willow Dr
Wooldridge Dr</td><td>Medium</td><td>Medium</td><td>High</td><td>Medium</td></tr>
<tr><td>Remaining roads listed under “Assets Evaluated”</td><td>Low</td><td>Medium</td><td>High</td><td>Medium-Low</td></tr>
<tr><td>Natural Resources</td><td>Kelp and eelgrass beds
Beaches
Wetlands
Freshwater ponds</td><td>Medium</td><td>High</td><td>Low</td><td>Medium-High</td></tr>
<tr><td rowspan="5">Recreation</td><td>Birch Bay Village Golf Course</td><td>Medium</td><td>Medium</td><td>Medium</td><td>Medium</td></tr>
<tr><td>Birch Bay Village Marina</td><td>Low</td><td>Medium</td><td>Medium</td><td>Medium-Low</td></tr>
<tr><td>Parks
Birch Bay State Park</td><td>High</td><td rowspan="3">Low</td><td rowspan="3">High</td><td>Medium-Low</td></tr>
<tr><td>Parks
Sand Dollar Park
Birch Beach
Sunrise Park
Heron Center</td><td>Medium</td><td>Medium-Low</td></tr>
<tr><td>Parks
Sunset Park
Lighthouse Park
Marina View Park
Dockside Park</td><td>Low</td><td>Low</td></tr>
</table>

6. ACTION PLAN

This section provides a summary of recommendations and identifies potential adaptation strategies to reduce the County's vulnerability to impacts from sea level rise and compound flooding. The Action Plan provides a starting point and presents initial suggestions for consideration, but more detailed planning will be needed to determine specific adaptation responses. Section 6.1 provides a list of potential actions that could be employed in the County to reduce or avoid the vulnerabilities of public and private coastal and riverine resources and communities. Adaptation measures are compiled in the following categories: non-structural measures, structural measures, and policy measures.

In recognition of the complexity of implementing various adaptation measures, Section 6.2 includes information on tools, programs, policies, funding sources, and financing mechanisms that can help the County prioritize and implement the adaptation strategies.

6.1 Adaptation Measures

Adaptation strategies are implementation projects or policies that help reduce the County's vulnerability to sea-level rise. Some of these strategies may require revisions to existing County policy, regulatory, and procedural tools; creation of new tools and programs; identification of funding sources; and project-level planning, design, and construction. This section identifies potential adaptation strategies including existing strategies developed in other planning efforts (Section 6.1.1), an overview of general sea-level rise adaptation approaches (Section 6.1.2), and a review of potential sea-level rise adaptation strategies for the County to explore in more detail (Section 6.1.3).

6.1.1 Existing Adaptation Strategies

The following section presents sea-level rise-related adaptation strategies and actions from other County, Tribal, and state planning efforts that could be considered in this next phase of this effort. Many of the strategies are presented verbatim from the associated documents.

Whatcom County Climate Action Plan (Whatcom County, Nov 2021)

In November of 2021, the Whatcom County Council adopted the 2021 Climate Action Plan, which lays out an array of adaptation strategies and actions for the county to pursue. Sea-level rise-related adaptation strategies and actions from the plan include:

- Transportation
  - Incorporate climate adaptation considerations into all County transportation planning processes.
    - Design new transportation infrastructure to withstand projected future climate impacts based on the intended lifespan of the infrastructure.
    - Incorporate climate change projections into future Natural Hazards Mitigation plans.

- Land Use
  - Build green infrastructure to enhance climate resilience and reduce environmental impact.
    - Develop a climate resilient infrastructure plan that identifies, protects, connects, and enhances ecosystem resilience. Require all new county infrastructure to meet resilient criteria. Plan should identify critical infrastructure, such as roads, bridges, and emergency services at risk in climate impact zones or related hazardous areas and a plan to upgrade or relocate.
    - Avoid infrastructure development in critical watershed areas, wetlands, high value ecosystems, and climate impact zones.
    - Prioritize replacement or retrofitting all county culverts that impact fish passage with fish friendly and climate resilient alternatives.
  - Protect climate-sensitive natural resources of high ecological value: Protect riparian corridors, floodplains, shorelines, wetlands, and migration corridors by incorporating science-based future climate scenarios in County code and increasing acquisition of voluntary conservation easements.
    - Accelerate and increase funding for the County's Conservation Easement Program to compensate landowners willing to sell conservation easements.
    - Revise zoning codes to reduce development potential in high value working lands and ecosystem areas, including the Rural Study Areas and climate impact zones. Consider zoning changes based on water availability. Compensate landowners subject to a rezone based on the estimated value of the rights removed.
    - Update the Whatcom County Comprehensive Plan (Whatcom County 2022) to require 1) net ecological gain as a component of land use actions, and 2) vulnerability assessments using science-based future climate scenarios.
    - Develop and implement a county ecosystem conservation plan or program that implements protection of critical habitat, critical core wildlife habitat, and climate migration corridors, and incorporate into relevant county plans and codes, as currently assigned to the Wildlife Advisory Committee.
- Water Resources, Fisheries, and Ecosystems
  - Maintain and enhance estuarine, marine shoreline and coastal wetland habitats for fish and shellfish.
    - Include climate change and sea level rise in the codes and regulations associated with the Shoreline Management Program.
    - Facilitate shoreward migration of coastal wetlands though removal of hard shore protection (e.g., bulkheads, dikes, seawalls) or other barriers to tidal flow and habitat.
    - Promote and maintain mechanisms for sediment transport and deposition.
  - Promote climate resilience by incorporating climate scenarios in all aspects of floodplain management and infrastructure needs.
    - Incorporate probabilistic scenarios for riverine/coastal flooding to inform planning and management and restrict development in the floodplain zone.

        - Inform landowners, developers, and contractors about the climate change risks of developing in the floodplain (Conservation Reserve Program - CRP).
        - Modify flood zone designations, and update County code to incorporate sea level rise/storm surge and increased peak flows.
    - Use natural processes that increase the capacity to store floodwaters and attenuate flood peaks to reduce flood risk.
        - Identify and prioritize opportunities to reconnect floodplains by removing, lowering, or setting back levees to reduce maintenance costs, reduce flood risk, and increase opportunity for restoration.
        - Restore riparian vegetation and wetlands within floodplains, including prioritization of 300' landward of the historic migration zone.
    - Reduce flood risk by moving people and infrastructure out of harm's way.
        - Identify critical infrastructure at risk of river/coastal flooding and relocate as needed.
        - Evaluate public and private developments and develop managed retreat plans as appropriate.
        - Acquire properties in the floodplain to reduce repetitive flood loss, reduce need for flood protection, and allow for floodplain restoration.
        - Remove development rights within floodplains through voluntary and regulatory pathways.
    - Manage stormwater infrastructure for increased frequency and magnitude of rainfall/flood events.
        - Incorporate future climate scenarios into stormwater management.
- Agriculture
    - Incorporate projected climate change impacts into revised land use and development codes to reduce destruction and increase the climate resilience of vulnerable ecosystems.
        - Update County Code to require climate vulnerability assessments when permitting new development or land use projects in or adjacent to climate impact zones (100+ year floodplains, coastal shorelines, geohazard areas, etc.), such as the Shoreline Management Program given impacts such as sea level rise.

Lummi Nation Climate Change Mitigation and Adaptation Plan: 2016-2026 (Lummi Natural Resources Department, 2016)

The Lummi Nation developed this plan to evaluate the potential impacts of climate change on and mitigation and adaptation strategies for the Lummi Indian Reservation, Lummi Usual and Accustomed Grounds and Stations, and Lummi Traditional Territories. With respect to sea-level rise, relevant strategies and actions from the plan include:

- Reduce the risk of property damage from coastal flooding and shoreline erosion.
    - Continue to assess coastal areas for flooding and erosion risks.
    - Facilitate managed retreat through land acquisition, zoning changes, development restrictions, and/or other regulatory tools as appropriate.

  - Protect coastal buildings and infrastructure through shoreline hardening and/or building elevation and floodproofing.
  - Encourage soft bank protection rather than traditional shoreline armoring.
- Maintain and enhance coastal wetland habitats.
  - Facilitate shoreward migration of coastal wetlands though land acquisition and removal of hard shore protection (e.g., bulkheads, dikes, sea walls) or other barriers to tidal flow.
  - Preserve and restore structural complexity and biological diversity when undertaking wetland enhancement activities.
  - Promote and maintain mechanisms for sediment transport and deposition.
- Protect the potable groundwater systems on and adjacent to the Reservation.
  - Reduce groundwater withdrawals by implementing voluntary, economic, and/or mandatory water conservation measures.
- Reduce the risk of damage to or failure of wastewater treatment infrastructure.
  - Identify wastewater treatment system vulnerabilities, develop site-specific adaptation strategies, and secure funding for improvement or replacement.

Nooksack Indian Tribe Climate Change Adaptation Plan for Key Species and Habitats (CIG and Nooksack Indian Tribe 2020)

The Nooksack Indian Tribe Natural and Cultural Resources Department collaborated with UW CIG to develop a vulnerability assessment and adaptation plan focused on the Tribe's priority species and habitats within the Nooksack River watershed and associated marine areas. Sea-level rise-related adaptation strategies and actions from the plan include:

- Increase resilience to sea level rise and shoreline erosion by maintaining and restoring estuary habitat.
  - Identify and restore pocket estuaries and eelgrass beds, important habitat for many fish and crustacean species, through fill removal or sediment deposition.
  - Incorporate best available sea level rise projections in restoration site designs.
  - Consider land exchange programs where landowners exchange property in the floodplain for county-owned land outside of the floodplain.
  - Integrate coastal management that accounts for sea level rise into land use planning.
- Where possible, limit the use of shoreline armoring and development to improve the resilience of nearshore habitats to sea level rise and erosion.
  - Where possible, prevent, prohibit, and remove barriers, armoring, or other structures used to protect structures from wave-drive erosion or flooding.

Addressing Sea Level Rise in Shoreline Master Programs (Ecology, 2017)

The Shoreline Master Program (SMP) Guidelines encourage local governments to consult Ecology's guidance for applicable new information on topics such as sea level rise [WAC 173-26-090(1)]. However, the existing SMP guidelines do not currently require local governments to consider sea-level rise within SMPs. Ecology subsequently developed guidance for addressing sea-level rise in SMPs in 2010 (revised 2017). The guidance provides additional information concerning sea-level rise projections, anticipated sea-level rise impacts, and suggestions for how specific sections of SMPs might include sea-level rise considerations (e.g., general policies, shoreline access, flood hazard policies, etc.). This guidance has been considered and is reflected in ESA's suggested adaptation strategies and recommended next steps throughout this section. New legislation passed in 2023 directs Ecology to update the SMP guidelines to address the impact of sea level rise and increased storm severity on people, property, and shoreline natural resources and the environment. This update will take place in the coming years.

Lessons Learned from Local Governments Incorporating Sea Level Rise in Shoreline Master Programs (Ecology, 2021)

Ecology released a report in July of 2021 that included sea-level rise case studies, success strategies, challenges, needs, and opportunities for local governments to incorporate sea-level rise in their SMPs. Whatcom County has already taken the suggested step of performing a vulnerability assessment (i.e., this report), which will be used to advance sea-level rise considerations in its SMP (WCC Title 23 1976). Future adaptation planning efforts should look to this document as well as the Washington Coastal Hazards Resilience Network[25] for further guidance and adaptation planning resources.

Sustainable Remediation: Climate Change Resiliency and Green Remediation (Ecology, 2023)

Ecology regulates contaminated site cleanup in Washington State to reduce exposure to contaminants and restore terrestrial and aquatic habitats. Ecology conducted a vulnerability assessment of cleanup sites across the state to identify those most at risk from the impacts of climate change. Sea-level rise was identified as the highest risk for sites in or near marine and tidally influenced areas. Recommended strategies related to sea-level rise and contaminated sites include:

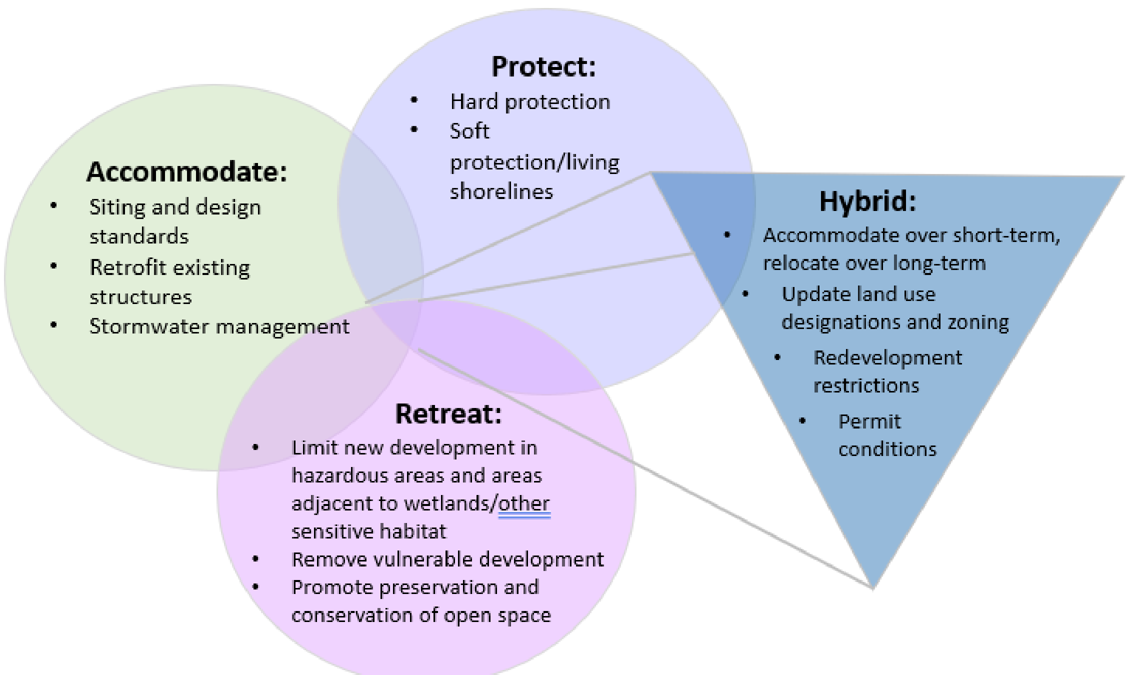
- Invest in shoreline stabilization techniques, such as berms, wetlands, marshes, soft armoring, hard armoring, and wave attenuation structures.
- Install alarm systems and the capability to remotely stop pumping equipment during storm events.
- Have backup power and built-in redundancy for storm events, along with an emergency response plan.
- Design containment remedies to withstand more severe storm events and flooding.

[25] https://wacoastalnetwork.com/

- Use "green" infrastructure or low impact development and flood control systems (e.g., marsh and wetlands; stormwater modular wetland passive treatment systems; earthen structures; permeable pavement; vegetated swales; berms; retention ponds) to reduce flood or stormwater overflow on land, and limit drainage to the sediment cleanup site or surface water.

6.1.2 General Adaptation Strategies

This section identifies general sea-level rise adaptation strategies based on industry best practices and state guidance (Ecology 2017, 2021; Miller et al. 2022). Different types of strategies (illustrated in **Figure 6-1**) will be appropriate in different locations, and, in some cases, a hybrid approach with strategies from multiple categories may be the best option. Additionally, the suite of strategies chosen may need to change over time as conditions change and previous areas of uncertainty and unknown variables become more certain.



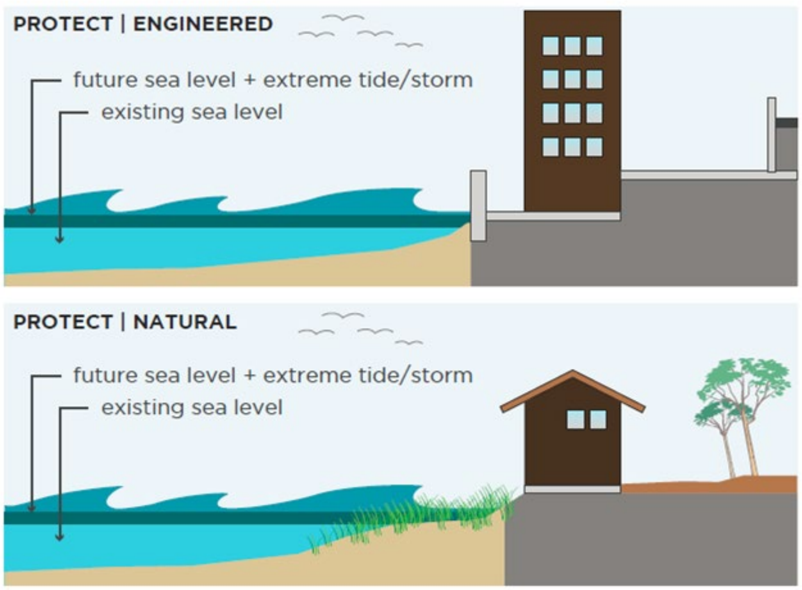
SOURCE: Modified from California Coastal Commission Sea Level Rise Policy Guidance, 2018

Whatcom County Compound Flood Vulnerability and Risk Assessment

Figure 6-1
Sea-Level Rise Adaptation Strategies

Sea-level rise adaptation strategies are typically organized within the following categories: protection (**Figure 6-2**), accommodation (**Figure 6-3**), retreat (**Figure 6-4**), and hybrid. Each category is further defined below.

- **Protection** strategies, which employ some sort of engineered structure or other measure to defend development (or resources) in its current location without changes to the development itself. These strategies encompass structural and natural or nature-based approaches. Examples include shoreline protective devices such as seawalls, revetments, groins, and breakwaters, which defend against coastal hazards such as wave impacts, erosion, and flooding; natural or "green" methods like dynamic cobble revetments and artificial oyster reefs to buffer coastal areas; and hybrid approaches using both artificial and natural infrastructure. It is important to note that hard armoring can exacerbate erosion and may only serve as a short-term solution to protect critical waterfront infrastructure. The Birch Bay Drive and Pedestrian Facility project is an example of a natural shore infrastructure protection strategy, which is more resilient to sea-level rise because of the dynamic nature of the gravel beach and berm.



SOURCE: San Francisco SLR Action Plan

Whatcom County Compound Flood Vulnerability and Risk Assessment

Figure 6-2
Protective Adaptation Examples

- **Accommodation** strategies, which modify existing development or design new development in a way that decreases hazard risks and increases the resiliency of development. Examples include elevating and/or retrofitting structures and using materials that increase the strength of development. In Whatcom County, this could include floodproofing the first floor of buildings to accommodate high-water-level events or designing new development with first floors above a projected future base flood elevation.

SOURCE: San Francisco SLR Action Plan

Whatcom County Compound Flood Vulnerability and Risk Assessment

Figure 6-3
Accommodation Adaptation Example

- **Retreat** strategies, which relocate existing development, limit substantial redevelopment, and/or limit the construction of new development in vulnerable areas. One example of a retreat strategy might be revising development codes (e.g., SMPs) to halt new development in impacted areas.

SOURCE: San Francisco SLR Action Plan

Whatcom County Compound Flood Vulnerability and Risk Assessment

Figure 6-4
Retreat Adaptation Example

- **Hybrid** strategies, which may employ a combination of one or more of the aforementioned strategies. For example, temporary coastal armoring could be installed to buy time for a community to retreat.

6.1.3 Potential Adaptation Strategies for Whatcom County

This section expands upon the general adaptation strategies mentioned above and provides tools for jurisdictions and communities in Whatcom County to consider. **Appendix E** describes potential adaptation strategies, their potential benefits and challenges, and a conceptual cost comparison. Not all strategies will be appropriate for all shoreline communities in the county, particularly as shoreline modifications are regulated under the County's SMP. This list is not exhaustive but is intended to serve as a framework from which the County might build a more detailed adaptation plan. Potential adaptation measures include:

- Protect – Soft Shore Techniques

  - Beach nourishment
  - Habitat restoration
  - Coastal bluff erosion best management practices
  - Large wood management
- Protect – Hard Defensive Structures
  - Beach retention structures (such as groins or breakwaters)
  - Shoreline protection devices
- Accommodate – Adapting in Place
  - Elevating or waterproofing structures and infrastructure
  - Elevating property grades
- Retreat
  - Managed retreat strategies are those strategies that deliberately plan to relocate or remove existing development out of hazard areas and limit the construction of new development in vulnerable areas. They could include:
    - Limiting development in coastal hazard areas (e.g., update floodplain maps to replace 100-year with 500-year floodplain, zoning overlays, setback and buffer requirements, require sea level rise real estate disclosures).
    - Transferring, purchasing, and/or extinguishing development rights (e.g., buyouts, conservation easements, defeasible estates, zoning/land use code changes).
    - Working with and support landowners to remove or relocate structures located in current or future hazard zones.

It is worth noting that this list is not exhaustive, and a detailed assessment of the costs, benefits, and detriments of different strategies has not been completed. Appendix E provides more details on each type of potential adaptation measure.

6.2 Tools, Programs, Policies, Funding Sources, and Financing Mechanisms

This section describes the recommended tools, programs and policies, and funding sources that can help the County take action and implement adaptation strategies.

6.2.1 County Tools to Facilitate Implementation

The County can choose from a variety of existing policy, regulatory, and procedural tools to facilitate the implementation of the adaptation strategies. These include:

1) **Comprehensive Plan (Whatcom County 2022)** and Zoning/Land Use Regulations– Goals, objectives, policies, and implementation measures could be developed and incorporated into the Comprehensive Plan to ensure consistency with the Vulnerability and Risk Assessment.

Zoning code amendments could be proposed, consistent with the Comprehensive Plan changes.

2) **Shoreline Master Program (SMP) & Critical Areas Ordinance (CAO) –** The County could update the SMP (WCC Title 23 1976) and CAO (WCC Title 16.16 1977) to include policies to implement adaptation strategies and revise development code to address identified vulnerabilities and acceptable levels of risk.

3) **Natural Hazards Mitigation Plan Revision and Implementation –** The County could update the hazard mitigation plan to include an evaluation of the impact climate change will have on the natural hazards that face the County and to ensure consistency with the Vulnerability and Risk Assessment.

4) **Capital Improvement Program** and **Transportation Improvement Plan -** For adaptation strategies that require capital expenditures or improvements to transportation infrastructure with identified impacted areas, the Capital Improvement Program and Transportation Improvement Plan are appropriate places to address priorities, funding, and scheduling of implementing adaptation strategies as it relates to public infrastructure.

5) **Administrative policies, procedures, and initiatives**. The County could amend or create administrative policies, procedures, and initiatives that would direct County staff efforts towards implementation of certain adaptation planning actions, such as:

    a. Establishing a process and identifying a lead department for monitoring the trajectory of sea-level rise and coastal erosion.

    b. Participating in regional coordination efforts.

    c. Preparing and implementing an Adaptation Plan that acts as an interdepartmental, and possibly multi-jurisdictional, plan that details key steps to take over the next two to five years.

Amendments to these plans and programs can help to establish a policy, regulatory, and administrative framework for implementation. They could also improve the County's ability to seek funding from state and federal agencies.

6.2.2 Implementation Programs and Policies

The following are programs, policies, and standards that would serve to implement the adaptation strategies identified.

Regional Coordination

There are several key agencies that the County should coordinate with as it moves forward with adaptation planning. These include:

- U.S. Army Corps of Engineers (USACE – The County could explore and pursue partnerships with USACE in reconnaissance and feasibility studies for new projects related to navigation, coastal flood hazard reduction, and/or habitat restoration that would serve as adaptation strategies. USACE partners with local jurisdictions in joint local-federally sponsored projects and can provide Federal funding for implementation for projects that are shown to have a federal interest based on feasibility studies and cost/benefit ratios following USACE guidelines.

- State of Washington – The County should advocate for state and Federal resources to address environmental and economic impacts to State and Federal areas of interest, particularly the shoreline.
- Tribal – The County should maintain and enhance partnerships with the Lummi Nation and Nooksack Indian Tribe to address sea-level rise, flooding, and erosion impacts on Tribal infrastructure and treaty protected resources.
- Coastal Hazards Resilience Network – The County should continue participating in the Coastal Hazards Resilience Network to partner with other local communities and learn about best practices for implementing adaptation planning.

Education and Outreach Programs

Engaging and communicating with the community on an ongoing basis is essential to ensuring that adaptation strategies can be successfully and efficiently implemented. Public engagement offers the opportunity to educate and build commitment and consensus among decision-makers and community members. The following are outreach materials and programs the County could implement:

1) Develop a "Property Owner's Guide to Preparing for Sea-Level Rise and Erosion" to help property owners navigate the regulatory system to elevate, retrofit, or move structures to accommodate sea-level rise and coastal erosion. Topics could cover:
    a. County permitting process
    b. Agency compliance (Ecology, FEMA, etc.)
    c. Key sea-level rise and erosion hazard standards
2) Develop and distribute technical information and guidance on home retrofitting options, which could include elevation, wet/dry flood proofing, flood gates, drainage improvements, hard armoring removal (e.g., partnering with Shore Friendly), and voluntary retreat from the shoreline, etc.
3) Establish a citizen's monitoring program for community members to gather reliable data on sea-level rise and erosion impacts, which could include measuring beach widths, documenting king tides and flooding, documenting flooding and property damage, etc.
4) Pursue funding and partnerships to formalize a sea-level rise public education program for high school students.

Community Plans

The County could facilitate the development of Community Plans for Adapting to Coastal Hazards in conjunction with community members and asset managers for smaller scale planning centered around vulnerable areas such as Sandy Point or Birch Bay. The development of such plans would require the following steps:

- Identify subarea boundaries for prioritization, possibly based on timing, area of impact, costs, equity, environment, economy, etc.;
- Develop planning timeframes around the point at which flooding creates recurring significant problems; and
- Evaluate adaptation alternatives with cost estimates in more detail, which may include armoring, elevation, realignment, etc.

Overlay Zones

An overlay zone is a land use planning tool which establishes additional regulations and incentives over an existing base zone. Special provisions, identified as part of the overlay zone, would supersede those provisions of the base zone, where applicable, to promote orderly planned development and to provide protection of the public's health, safety, and general welfare. An overlay zone could provide for a consolidated set of coastal hazard and sea-level rise land use regulations. For example, studies, disclosures, or development standards could be required for properties located within the overlay zone. The process for designating overlay zones could include the development of coastal flood and erosion maps that include areas that will be subject to tidal inundation, wave action, storm flooding, and erosion due to sea-level rise, such as those maps developed for this study. The maps would need to be regularly updated to reflect the best available science on sea-level rise projections and associated hazard zones.

If the overlay zone is additional to the designations in the SMP, any requirements would need to be reviewed for consistency with the SMP and underlying environment designation and associated policies and regulations.

Flood Resiliency Standards

Applicable building codes could be revised to enable structures to withstand higher water levels within areas susceptible to sea-level rise hazards. Standards could require:

- Increased base floor elevations.
- Limited first floor habitable space.
- Floodable or waterproof standards.
- Lower thresholds triggering floodproofing requirements for existing structures.

As described in Section 1.2.3, raising existing structures would help to limit damage from coastal and river/creek flooding. Standards for new development could require structures to account for additional freeboard elevation to accommodate anticipated levels of sea-level rise for the expected life of the structure. This requirement would be in addition to the existing requirement that structures be raised above the base flood elevation as established on FEMA National Flood Insurance Rate Maps. The sea-level rise amount would be calibrated to the amount of sea-level rise that could occur during the anticipated life of the structure according to the best available science (e.g., 75 years for residential). Abandoning the lowest floor or elevating the lowest habitable floor are also effective strategies in reducing damage to the buildings.

Floodable standards involve adapting a home to allow floodwaters to enter and exit without causing major damage to the home or its contents. Floodable or wet flood proofing measures include, flood openings, elevating building utilities, flood proofing building utilities, or the use of flood damage-resistant materials. Waterproofing, or dry flood proofing, measures involve sealing the structure to prevent floodwaters from entering. Barrier measures can be built around a structure to contain or control flood waters, including floodwalls or levees with or without gates (FEMA 2019).

Real Estate Disclosure

Upon any real estate transaction, this policy strategy would require the disclosure of potential hazards to buyers of property in a coastal hazard zone. This disclosure would inform buyers of potential hazards associated with the established coastal hazard zone, including erosion, coastal flooding, and tidal inundation, as a result of sea-level rise. The inclusion of this type of disclosure provides limited liability protections for the local jurisdiction and educates landowners and potential buyers on the risk of owning property in a hazardous area. The state currently mandates a variety of disclosures during real estate transactions, including geologic and existing flood hazard risks as mapped by FEMA. The current state-mandated real estate disclosures do not include disclosures of hazards related to sea-level rise. This is an issue the County could potentially add to its legislative platform and work with the State to change.

6.2.3 Funding Sources and Mechanisms

Adaptation planning is a challenging undertaking and will require substantial funding to design, permit, implement, and maintain adaptation strategies. Although there are state and federal grant programs that are available to support adaptation planning, to sustainably implement adaptation strategies, a community should develop a layered funding strategy that starts with local investment, and leverages those monies with grants, loans, and private sector investments. This demonstrates the community’s commitment to a more self-reliant financial future while increasing the likelihood of securing grants which are oftentimes contingent upon a local funding match. This section identifies both grant funding opportunities as well as local funding strategies, both of which will require proactive planning by the County to successfully procure or implement, particularly local funding strategies which in several cases require voter approval.

Grant Funding Sources

FEMA Hazard Mitigation Assistance

FEMA administers four programs that provide assistance to local governments (as well as state and tribal governments) for reducing the risk of loss of life and property from future disasters.

1) The Hazard Mitigation Grant Program assists in implementing long-term hazard mitigation planning and projects following a Presidential major disaster declaration. Typical mitigation projects funded through the Hazard Mitigation Grant Program include:
   - Acquisition and structure demolition/relocation
   - Preparation of hazard mitigation plans

  - Mitigating flood conditions, such as through floodplain and stream restoration or green infrastructure methods
  - Raising homes or structural retrofitting existing buildings

2) The Pre-Disaster Mitigation Program provides funds for hazard mitigation planning and projects on an annual basis, including the development and implementation of hazard mitigation plans. The goal is to reduce overall risk to the population and structures from future hazard events, while also reducing reliance on Federal funding in future disasters. This program awards planning and project grants and provides opportunities for raising public awareness about reducing future losses before disaster strikes. Grants are funded annually by Congressional appropriations and are awarded on a nationally competitive basis.

3) The Flood Mitigation Assistance Program provides funds for planning and projects to reduce or eliminate the risk of flood damage to buildings that are insured under the National Flood Insurance Program on an annual basis. Generally, local communities will sponsor applications on behalf of homeowners and then submit the applications to the State. Funding is appropriated by Congress annually.

4) The Building Resilient Infrastructure and Communities (BRIC) program provides funds to support capacity and partnership building projects related to floods, extreme heat, wildfires, and more natural disasters. In addition to grant funding, BRIC offers non-financial technical assistance in the form of administrative, technical writing, and outreach and communications support.

NOAA Climate Resilience Regional Challenge

The Climate Resilience Regional Challenge was announced in June 2023 as an opportunity to fund collaborative coastal resilience projects that address risk reduction and equitable adaptation initiatives. There are two tracks: (1) Regional Collaborative Building and Strategy Development and (2) Implementation of Resilience and Adaptation Actions. Track 1 focuses on planning and capacity building efforts, while Track 2 prioritizes implementation of adaptation projects. In addition to grant funding, the program offers technical assistance including data, tools, and training.

Shore Friendly

This statewide program offers financial and technical assistance to waterfront property owners throughout Puget Sound. The Northwest Straits Foundation manages the Shore Friendly Landowner Outreach program to provide assistance and incentives to shoreline owners to become informed stewards of coastal properties. This includes site visits and property assessments, design and technical assistance to facilitate the conversion from hard to soft shoreline armoring, and financial solutions including cost sharing and mini grants for armoring removal, habitat restoration, drainage improvements, and home relocation.

Potential Funding Mechanisms

Assessment and Abatement Districts

The purpose of an assessment or abatement district is to establish a mechanism by which a city or county can finance the prevention, mitigation, abatement or control of some type of pest, nuisance or hazard. For the purposes of hazards related to beach and bluff front property, Coastal Hazard Assessment Districts (CHADs) and Geologic Hazard and Abatement Districts (GHADs) can be established to implement adaptation strategies described above. CHADs provide a funding reserve for future maintenance, expansion, and rehabilitation of flood and/or erosion control structures. Often financed through the collection of supplemental tax assessments, CHAD revenues are relatively safe with the option to borrow from lenders or issue bonds with attractive credit terms. The establishment of a CHAD or GHAD would allow for the better assessment of hazards, as well as increased funding for maintenance, repairs or other similar improvements. This often results in a greater funding reserve and improved maintenance or repair services.

Establishment of a Shoreline Account

A “Shoreline Account” could be established to serve as the primary account where funds generated for future adaptation programs would be kept in reserve. Funds, subject to the restrictions of any terms of the funding sources, may be used to pay for adaptation-related projects, including the cost to repair and maintain, and to pay for conducting surveys and monitoring programs.

Mitigation Fees or In-Lieu Fees

Mitigation fees or in-lieu fees can generate funds for implementing adaptation strategies. Fees could be established to generate revenues to cover the cost to plan for and implement adaptation strategies. Under this program, property owners would be required to pay mitigation fees as a condition of approval for a coastal development permit. Funds from these fees could be used to implement projects that provide sand to the county’s beaches and public recreation/access projects that direct recreation and/or access benefit to the general public.

7. NEXT STEPS

This study presented the results of a County-wide compound flooding vulnerability and risk analysis that is intended to provide the basis for future site-specific assessments and broader adaptation planning. Based on the findings of this study, the following next steps are recommended:

1. Expand the Vulnerability Assessment:

    a. Extend the Vulnerability Assessment up the Nooksack River: the USGS Lower Nooksack River modeling focused on the compound impacts of sea-level rise and increased precipitation. Impacts due to sea-level rise only extend up to a certain portion of the river. As a result, the USGS focused on the lower Nooksack River from Ferndale to the mouth. A future study could assess the impacts of increased precipitation further up the river and evaluate the exposure, sensitivity, and adaptive capacity of assets in the floodplain to determine the County's vulnerability to riverine flooding with climate change.

    b. Extend the Vulnerability Assessment along the coastline (beyond just Sandy Point and Birch Bay): While the scope of this assessment focused on two specific areas to evaluate vulnerability, a future study could assess the impacts of sea-level rise along the full county coastline and evaluate the exposure, sensitivity, and adaptive capacity of assets in the floodplain.

    c. Conduct a detailed coastal change and erosion analysis and long-term monitoring program: Since CoSMoS does not include geomorphic responses and their influences on the spatial extent of flooding, a more detailed erosion analysis could be conducted to better understand how the shoreline may change in the future. Due to data limitations, the erosion hazard zone in this study should be considered a planning-level tool that provides the County with a high-level estimate of the potential scale of impact due to erosion. A more detailed analysis could include a delineation of the toe and top of bluffs and wetted beach from aerial imagery, evaluating historic shoreline positions to study past erosion, and conducting beach geomorphology analyses to understand how the beach would change with sea-level rise. The results of this analysis could also be used to adjust the flood extent in the hazard zone based on the predicted future geomorphology.

    d. Conduct habitat evolution/migration modeling: While some habitat data were available for this study, the exposure analysis was focused on risks due to inundation and erosion which are often natural and necessary processes for intertidal and subtidal habitats. Habitat evolution modeling[26,27] (e.g., how habitats are expected to move upslope with increasing sea levels based on inundation frequency and salinity exposure) can be used to better understand how coastal habitats will be impacted with sea-level rise (ESA 2015, ESA 2018). This type of modeling could help identify areas to preserve for future restoration and areas most at risk of being submerged under future climate conditions.

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[26] https://www.delmar.ca.us/DocumentCenter/View/4314/Final-Summary_Wetland-Habitat-Migration-Assessment_8162018

[27] See Appendix K (page 172) http://www.lospenasquitos.org/wp-content/uploads/2020/09/ESA-FINAL-Los-Penasquitos-Lagoon-Enhancement-Plan-APPENDICES.pdf

2. Develop a full Adaptation Plan: Through a public outreach process and in coordination with project partners, the County could develop preferred adaptation scenarios for different areas of the county, such as Sandy Point or along the Nooksack River, as part of an Adaptation Plan. A preferred scenario would likely be a combination of the adaptation strategies identified in Appendix E that would be implemented based on monitored triggers (e.g., a certain amount of sea-level rise, flooding more frequent than every year, a certain amount of bluff-top erosion). The plan could include a cost-benefit analysis to understand the tradeoffs of implementing expensive adaptation measures versus the damage that could be caused by flooding and erosion. The plan should also include identification of monitoring priorities (e.g., high water marks during flood events, water level data from gage network, sea level trends, the best available science) and adaptation triggers. Lastly, the plan could include potential policy language that could be incorporated into the plans listed in #3 below. Since planning documents are updated on specific timelines, developing policy language as part of an Adaptation Plan would provide the County with text specific to reducing compound flood risks due to climate change that could easily be added to each plan as it is updated (even if that is several years in the future). More and more resiliency funding is becoming available through federal and state grants and is often focused on multi-jurisdictional teams, similar to the one the County has developed for this project. The County should continue to work with project partners to develop proof-of-concept adaptation strategies.

    a. Monitor erosion: Working with regional partners and research institutes, the County could support development of an erosion monitoring program in Puget Sound. For example, the County could work with Ecology to expand the monitoring that was done at Point Roberts and Point Whitehorn (Weiner et al. 2018). Alternatively, the County could identify new bluff top locations and beach cross-sections to regularly monitor for erosion. This data could be used to track high-erosion-risk areas and potentially refine the erosion hazard zone in the future.

    b. Develop a coastal armoring geodatabase: Working with regional partners and research institutes, the County could support expanding Ecology's Coastal Atlas[28] coastal armoring data for Puget Sound. Information about the location, extent, and type of shoreline armor is a key piece of information when considering erosion and flooding because armored shorelines can reduce natural erosion from occurring and may cause exacerbated flooding or erosion for adjacent areas and can severely degrade coastal habitats such as forage fish spawning areas Since armoring is a potential adaptation strategy that landowners may pursue, gathering existing data can be helpful to inform a County-wide Adaptation Plan and potential suitability of armoring versus other alternatives at a site. Ecology has started this work, developing an armored shoreline inventory that includes Point Roberts and Point Whitehorn within Whatcom County (Weiner et al. 2018).

3. Implement adaptation strategies through local planning documents:

    a. Update the SMP (WCC Title 23 1976), zoning, land division, and critical areas codes: Update regulations to reflect the results of this study, incorporate adaptation planning, and minimize risk to public and private assets.

[28] https://apps.ecology.wa.gov/coastalatlasmap

b. Update the Hazard Mitigation Plan: Incorporate policy recommendations to meet new standards under FEMA's Local Mitigation Planning Policy[29].

c. Incorporate results and recommendations into the Comprehensive Plan Update: Update goals and policies to reflect the results of this study and incorporate adaptation planning.

d. Incorporate results and recommendations into coastal and riverine floodplain planning processes and plans.

[29] https://www.fema.gov/sites/default/files/documents/fema_local-mitigation-planning-policy-guide_042022.pdf

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Appendix A. Whatcom County Coastal and Riverine Compound Flood Vulnerability and Risk Assessment – Bluff Erosion Estimates (CGS 2023)

memorandum

Date: June 21, 2023

To: Lindsey Sheehan, Principal Engineer, ESA

From: Avery Maverick, LG, MS, and Jim Johannessen, LEG, MS, Coastal Geologic Services, Inc.

Re: **Whatcom County Coastal and Riverine Compound Flood Vulnerability and Risk Assessment – Bluff Erosion Estimates-V2**

Introduction and Purpose

The purpose of the brief memo is to describe the methods for estimating bluff recession[1] rates for Whatcom County shores to assist Environmental Science Associates (ESA) in the *Whatcom County Coastal Riverine Compound Flood Vulnerability and Risk Assessment*. The goal of this specific assessment is to provide a basis for the development of bluff hazard zones along Whatcom County bluff backed shores. While this assessment uses quantitative data as the foundation, this analysis was limited to a high level based on readily available data and budget constraints. Future studies would benefit from the incorporation of additional data and analyses.

Methods

To estimate historic bluff recession rates across Whatcom County bluff backed shores, we utilized measured long-term bluff recession rates that were compiled and analyzed by CGS as a part of a project for the Estuary and Salmon Restoration Program (Coastal Geologic Services 2018). The bluff recession rates dataset includes 185 long-term recession rates from throughout the region that were measured across several decades ranging from 23 to 101 years. Recession rates were measured using two approaches: historical air photo analysis in GIS and field-based measurements from government survey monuments to the bluff crest or toe. It is important to note that the recession rates from this study likely overestimate average recession rates in Puget Sound due to the measurement methods applied and the sites chosen for the project.

For this specific assessment we chose to estimate historic bluff recession rates for the three main categories of bluff shoretypes mapped along Whatcom County:

- **Feeder Bluffs (FB) -** bluffs that experience significant erosion and contribute sand and gravel to local beaches, although not as significant as the "exceptional" category (FBE). These bluffs vary greatly in height and the character of erosion, depending on local geologic factors. Evidence for feeder bluffs generally consists of active erosion, fallen trees, and indications of recent landslides. We also include the **Feeder Bluff Talus (FB-T)** category here, which are rocky bluffs

[1] The terms "bluff recession" and "erosion" are sometimes used interchangeably, however recession is the net landward movement of the landform due to both erosion and mass wasting (landslides) and is expressed as a horizontal change in distance. Landward recession is expressed as a negative number (Coastal Geologic Services 2018).

that erode slowly. These only occur on the southwest shores of Lummi Island within Whatcom County.

- **Feeder Bluff Exceptional (FBE) -** bluffs that are among the most rapidly eroding shorelines on Puget Sound and deliver large volumes of sediment to the beach. Exceptional feeder bluffs typically consist of abundant and easily erodible sand and gravel. Evidence for these bluffs includes active erosion and landsliding. Eroded material (colluvium) is often found at the base of the slope and vegetation on the face of the bluff is unusual.
- **Transport zones (TZ) -** beaches backed by relatively stable bluffs with little active erosion. These segments do not contribute appreciable amounts of sediment to the littoral system and might be thought of as "neutral" or "non-contributing" bluffs. Transport zones lack typical indicators of erosion such as toe erosion and active landslides. Slopes often support conifers and other established vegetation communities.

Based on shoreform mapping from CGS's Beach Strategies (Coastal Geologic Services 2017), there are approximately 42 miles of bluff backed shorelines in Whatcom County, or about 29% of Whatcom County shores.

For each of the bluff shoreforms, we queried the bluff recession database based on specific parameters. For feeder bluff shores, we average six of the seven rates measured at feeder bluffs within Whatcom County. We omitted one point within Whatcom County along north Lummi Bay due to some uncertainty with the original digitizing. These ranged from a low of -0.26 FT/YR to a high of -0.77 FT/YR, with an average of -0.48 FT/YR. For feeder bluff exceptional shores, we estimated that the rate would be 0.1 FT/YR faster than feeder bluff shores, or -0.58 FT/YR. This was based on results of the bluff recession rate report which stated that feeder bluff exceptional shores had bluff recession rates of 0.1 FT/YR faster than feeder bluffs, controlling for surface geology, bluff EPR feature, measured fetch, and tidal range. For transport zone shores, we queried the entire dataset, as there are no transport zone rates within Whatcom County, based on transport zone sites that have similar statistically significant conditions. We averaged sites that had a tidal range between 8-10 FT and a fetch distance greater than 5 miles, which equated to -0.31 FT/YR.

Results and Conclusions

Based on our analysis we recommend the following historic bluff recession rates for the different shoretypes:

- Feeder Bluff (FB) and Feeder Bluff Talus (FB-T): **-0.48 FT/YR**
- Feeder Bluff Exceptional (FBE): **-0.58 FT/YR**
- Transport Zone (TZ): **-0.31 FT/YR**

These estimates are likely an overestimate of the average historic recession rates in Whatcom County, based on the input data and our knowledge of Whatcom County bluffs. Due to climate change, however, which is shown to increase heavy precipitation events and result in accelerating sea level rise, these rates provide a conservative estimate to use for high level planning and erosion analysis. We recommend that these rates be applied for current (recent) trends to their respective mapped shoreforms from Beach Strategies. Ideally, a planning horizon would be identified, and these rates would then be used to create hazard zones that would be mapped from the bluff crest landward with an additional buffer of safety added. However, if budget constraints do not allow for this, it is important to identify a reasonable location and a method from which to build the hazard zones. Future assessment would greatly benefit from additional data, including using more local recession rates (CGS has more existing data that would need to be compiled and analyzed after acquiring permission for use) along with incorporating bluff crest mapping.

References

Coastal Geologic Services (MacLennan, A. J., Johannessen, J. W., Waggoner, J. F., Waddington, J., Lubeck, A. J.), 2018. Long-Term Bluff Recession Rates in the Puget Sound Region: Implications for the Prioritization and Design of Restoration Projects (Prepared for the Estuary and Salmon Restoration Program). Bellingham, WA.

Coastal Geologic Services (MacLennan, A. J., Rishel, B., Johannessen, J. W., Lubeck, A. J., Øde, L.), 2017. Beach Strategies Phase 1 Summary Report: Identifying Target Beaches to Restore and Protect (Prepared for the Estuary and Salmon Restoration Program No. 14–2308). Bellingham, WA.

Appendix B.
County-Wide Exposure Table

					King Tides (Coastal)			20-25-Year Coastal and Riverine Storm		100-Year Coastal Storm		Erosion		
					Present Day	Short-Term	Mid-Term	Short-Term	Mid-Term	Present Day	Long-Term	2040	2080	2100
Asset	Unit (Count, Miles, or Acres)	Total Analyzed	Data Extent	Data Notes	Current Sea Level	0.8 ft of SLR	3.3 ft of SLR	0.8ft of SLR	3.3 ft of SLR	Current Sea Level	6.6 ft of SLR	11 ft of Erosion	35 ft of Erosion	47 ft of Erosion
Parcels and Structures														
Parcels	Acres	519275.9	County	Total parcel acres as provided by Whatcom County. Includes waterbodies such as Lake Whatcom.	5,093	6,677	9,701	11,551	13,013	7,705	12,795	74	265	368
Buildings	Count	92214	County		133	487	2,238	1,508	2,814	1,977	2,836	94	189	273
Schools	Count	125	Western county		0	0	0	0	0	0	0	0	0	0
Libraries	Count	2	Bellingham		0	0	0	0	0	0	0	0	0	0
Housing Development	Count	2	Birch Bay	Category associated with Birch Bay Circle Grange and Birch Bay Leisure Park	0	0	1	1	1	1	1	0	0	0
Infrastructure														
Water Infrastructure:														
Distribution Stations	Count	13	Birch Bay		0	0	3	1	3	3	3	0	0	0
Lateral and Main Lines	Miles	678.8	Bellingham		3.0	6.3	13.5	16.1	21.9	8.4	27.2	0.0	0.3	0.4
Stormwater Infrastructure:														
Stormwater Drains	Miles	17.1	Birch Bay, Sandy Point, Bellingham		0.6	0.9	1.5	1.4	1.8	1.2	2.2	0.0	0.0	0.0
Stormwater Detention Ponds	Count	4.6	Birch Bay		0	0	5.0	2	5	5	5	0.0	0	0
Stormwater Inlets (i.e. catch basins)	Count	835	Birch Bay, Sandy Point		8	40	174	96	184	178	194	0	0	9
Stormwater Lines (lateral, main, & network)	Miles	559.6	Western county	Includes lines over major bodies of water (i.e. Lake Whatcom)	6.7	6.9	8.2	8.5	11.7	7.6	16.4	0.1	0.3	0.4
Sewer/Wastewater Infrastructure:														
Manholes	Count	844	Birch Bay		8	23	188	79	202	167	226	1	1	2
Lift Stations	Count	8	Birch Bay		1	1	7	2	7	6	8	0	0	0
Treatment Plants	Count	4	Bellingham		0	0	0	1	2	1	1	0	0	0
Mains (Gravity and Pressurized)	Miles	344.3	Bellingham		0.1	0.2	0.9	1.3	2.8	0.7	6.0	0.0	0.2	0.2
Lateral Lines	Miles	330.3	Bellingham		0.1	0.1	0.4	0.6	1.4	0.21	2.7	0.0	0.0	0.1
Natural Resources														
Freshwater Ponds	Count	135	Bellingham		0	0	1	0	1	1	1	0	0	0
Open Channel Creeks	Miles	1071.8	Western county		17.4	22.7	31.5	40.4	42.0	24.2	39.3	0.0	0.1	0.1
Emergency Services														
Fire Stations	Count	52	Western county		1	1	1	1	1	1	1	0	0	0
Fire Hydrants	Count	303	Birch Bay		1	2	70	21	78	63	82	0	0	1
Hospitals	Count	3	Birch Bay, Bellingham		0	0	0	0	0	0	0	0	0	0
Police Stations	Count	12	Western county		0	0	0	0	0	0	0	0	0	0
Communication														
Radio Tower	Count	7	Western county		0	0	0	1	1	0	1	0	0	0
Electric Power Facility	Count	3	Western county		0	0	0	0	0	0	1	0	0	0
Transportation														
Roads	Miles	2137.6	County		4.1	10.8	47.2	45.6	71.1	30.6	77.3	0.0	0.4	1.2
Railroads	Miles	99.85	Western county		0.4	0.6	1.1	2.4	3.8	1.6	11.3	0.0	0.1	0.3
Airport	Count	4	Sandy Point		0	0	0	0	1	0	1	0	0	0
Marina	Count	1	Western county		0	0	0	1	1	1	1	0	0	0
Bus Station	Count	2	Bellingham	Long distance buses (i.e. Greyhound)	0	0	0	0	1	0	1	0	0	0

					King Tides (Coastal)			20-25-Year Coastal and Riverine Storm		100-Year Coastal Storm		Erosion		
					Present Day	Short-Term	Mid-Term	Short-Term	Mid-Term	Present Day	Long-Term	2040	2080	2100
Asset	Unit (Count, Miles, or Acres)	Total Analyzed	Data Extent	Data Notes	Current Sea Level	0.8 ft of SLR	3.3 ft of SLR	0.8ft of SLR	3.3 ft of SLR	Current Sea Level	6.6 ft of SLR	11 ft of Erosion	35 ft of Erosion	47 ft of Erosion
Land Use														
Forest	Acres	56859.3	Bellingham		261	552	802	1,105	1,130	593	1,051	3.6	15.8	23.4
Restoration Sites	Acres	207.5	Bellingham		12.9	14.4	15.9	16.8	18.1	15.4	20.4	0.1	0.3	0.4
Agriculture	Acres	97579.3	Western county		2,197	2,919	3,831	4,801	4,927	3,077	4,787	0.6	0.9	0.9
Landmark	Count	32	Sandy Point, Bellingham area		6	6	7	6	8	7	8	0	0	0
Recreation														
Park	Acres	3985.1	Birch Bay, Sandy Point, Bellingham		100	109	128	126	149	120	177	0.0	0.0	0.0
Trails	Miles	133.7	SW county		0.9	1.1	1.8	3.9	4.5	1.6	4.8	0.0	0.6	1.3

** All values for the erosion and flooding with similar storm return periods (e.g., King Tide, 20yrs, 100yrs) are cumulative and assets at risk of erosion are not also counted in the flood scenarios.

Appendix C. Sandy Point Vulnerability Tables

<table>
<tr><th></th><th>Sandy Point Parcels and Structures</th></tr>
<tr><td>Assets Evaluated</td><td>▪ Fire Station
▪ Sandy Point Hatchery
▪ 606 Structures (Homes/Buildings)
▪ 182 Undeveloped Parcels</td></tr>
<tr><td rowspan="2">Exposure to Hazard and Consequences</td><td>▪ Under existing conditions (i.e., no SLR), 43 structures, including the fire station, and 114 undeveloped parcels flood annually during king tides. Five structures are also currently within the erosion hazard zone.
▪ 0.8 ft of SLR (2040-2060)
– 143 structures and 119 undeveloped parcels (all south of Cleo Rose Ln) expected to flood during king tides.
– During the 20-year event, 339 structures and 127 undeveloped parcels expected to flood.
– 75 structures expected to be in the erosion hazard zone by 2040.
▪ 3.3 ft of SLR (2080-2100)
– 417 structures and 130 undeveloped parcels expected to flood during king tides.
– During the 20-year event, 432 structures (all but 15 south of Cleo Rose Ln), and 133 undeveloped parcels expected to flood.
– 130 structures and 4 undeveloped parcels expected to be in the erosion hazard zone by 2080.
▪ 432 structures and 133 undeveloped parcels expected to flood during the 100-year event with 6.6 ft of SLR. 161 structures and 4 undeveloped parcels expected to be in the erosion hazard zone by 2100.</td></tr>
<tr><td>Hazard exposure grade:
▪ Fire Station: High
▪ Sandy Point Hatchery: n/a; not expected to flood under 100-year event with 6.6 ft of SLR
▪ Structures (Homes/Buildings): High (273), Medium (305), Low (15)
▪ Undeveloped Parcels: High (123), Medium (11), Low (3)</td></tr>
<tr><td rowspan="2">Sensitivity to Hazard</td><td>Flooding and erosion may impact emergency response capabilities and response time for the Fire Department. Increased frequency of flooding of structures leads to water damage and other flood related damages as well as disrupted access to and from buildings.</td></tr>
<tr><td>Sensitivity grade:
▪ Fire Station: High
▪ Structures (Homes/Buildings): Medium
▪ Undeveloped Parcels: Low</td></tr>
<tr><td rowspan="2">Adaptive Capacity of Asset</td><td>Long-term operational interruption if flooding or mechanical and plumbing systems are present on the ground floor and are subject to damage. As a public asset, the fire station will likely get priority for public funding for repairs, adaptation, or relocation compared to private structures. Structures south of Cleo Rose Ln will have lower adaptive capacity than north of Cleo Rose Ln, because roads and other infrastructure are expected to be more extensively impacted, making it challenging to rebuild.</td></tr>
<tr><td>Adaptive Capacity grade:
▪ Fire Station: Medium
▪ Structures (Homes/Buildings) North of Cleo Rose Ln: Medium
▪ Structures (Homes/Buildings) South of Cleo Rose Ln: Low
▪ Undeveloped Parcels: High</td></tr>
<tr><td>Vulnerability Summary</td><td>Overall Vulnerability grade:
▪ Fire Station: High
▪ Structures (Homes/Buildings) North of Cleo Rose Ln: Medium (34), Medium-Low (3)
▪ Structures (Homes/Buildings) South of Cleo Rose Ln: High (273), Medium-High (271), Medium-Low (12)
▪ Undeveloped Parcels: Medium-Low (132), Low (3)</td></tr>
</table>

<table>
<tr><th colspan="2">Sandy Point Infrastructure</th></tr>
<tr><td>Assets Evaluated</td><td>▪ Sandy Point Wastewater Treatment Plant
▪ Stormwater infrastructure (inlets and open drains)
▪ Roads:
– Saltspring Drive
– Mayne Lane
– Sucia Drive
– Matia Drive
– Patos Road
– Puffin Road
– Thetis Way
– Stuart Circle
– Cleo Rose Lane
– Tsata Lane
– Neptune Lane
– Germaine Road
– Beach Way
– Olympic Drive</td></tr>
<tr><td rowspan="2">Exposure to Hazard and Consequences</td><td>▪ Under existing conditions (i.e., no SLR), 8 storm drain inlets and the open drains along Patos Dr and south Sucia Drive flood during king tides.
▪ 0.8 ft of SLR (2040-2060)
– 19 storm drain inlets south of Cleo Rose Ln and the open drains along Saltspring Dr expected to flood during king tides.
– Most of Sucia Dr and Saltspring Dr flood south of Cleo Rose Ln, but <1 ft so probably still drivable during king tides.
– During 20-year event, 21 storm drain inlets expected to flood.
– During 20-year event, Patos Rd, Saltspring Dr, Sucia Dr, and Thetis Way expected to flood with >1 ft.
▪ 3.3 ft of SLR (2080-2100)
– During king tides, most of Sucia Dr and Saltspring Dr expected to flood south of Cleo Rose Ln with >1 ft depths, so probably not drivable → emergency access/egress lost. Mayne Ln, Patos Dr, Puffin Rd, Stuart Cir, Matia Dr, and Thetis Way also expected to flood with >1 ft depths.
– 21 storm drain inlets expected to flood during king tides.
– During 20-year event, Olympic Dr and S Beach Way also expected to flood. A low spot in Sucia Dr just south of S Beach Way floods by >1 ft, limiting access/egress for everyone south of that point.
▪ During the 100-year event with 6.6 ft of SLR, all roads south of Cleo Rose Ln expected to flood. The full length of Sucia Dr is expected to flood. Cleo Rose Ln, Tsata Ln, Neptune Ln, Germaine Rd. also expected to flood in addition to the roads that flood under the other scenarios. Open drains along Cleo Rose Ln and Tsata Ln expected to flood.</td></tr>
<tr><td>Hazard exposure grade:
▪ Sandy Point Wastewater Treatment Plant: n/a; not expected to flood under 100-year event with 6.6 ft of SLR
▪ Storm drain inlets: High (19), Medium (2)
▪ Open drains: High (3), Low (2)
▪ Roads:
– High: Sucia Dr, Saltspring Dr
– Medium: Patos Rd, Thetis Way, Mayne Ln, Puffin Rd, Matia Dr, Stuart Cir
– Low: Cleo Rose Ln, Tsata Ln, Neptune Ln, Germaine Rd, S Beach Way, Olympic Dr</td></tr>
<tr><td rowspan="2">Sensitivity to Hazard</td><td>Flooding may disrupt access pathways critical for emergency services as well as transportation links to local businesses, residences, and municipal infrastructure.
Flooding may lead to blockage of inlets or outlets. Tide gates are particularly susceptible to blockage due to high downstream water levels. Higher coastal water levels can cause insufficient capacity in the stormwater system for (potentially) increased rainfall. Failure of the storm drainage system can cause flooding inland of the coast and associated property damage as well as impacts to water quality.</td></tr>
<tr><td>Sensitivity grade:
▪ Storm drain inlets: Medium
▪ Open drains: Medium
▪ Roads
– Main ingress and egress (Sucia Dr, Saltspring Dr, S. Beach Way): High
– Other roads: Medium</td></tr>
</table>

Adaptive Capacity of Asset	Once water recedes, roads and stormwater infrastructure are likely to be operational fairly quickly.
	Adaptive Capacity grade: ▪ Storm drain inlets: High ▪ Open drains: High ▪ Roads: High
Vulnerability Summary	**Overall Vulnerability grade:** ▪ Storm drain inlets: Medium (19), Medium-Low (2) ▪ Open drains: Medium (3), Low (2) ▪ Roads: – Medium-High: Sucia Dr, Saltspring Dr – Medium-Low: S. Beach Way, Patos Rd, Thetis Way, Mayne Ln, Puffin Rd, Matia Dr, Stuart Cir – Low: Cleo Rose Ln, Tsata Ln, Neptune Ln, Germaine Rd, Olympic Dr

Sandy Point Natural Resources	
Natural Resources Evaluated	▪ Kelp and eelgrass beds ▪ Beaches ▪ Wetlands ▪ Freshwater pond (Agate Lake)
Exposure to Hazard and Consequences	– In general, sea level rise will reduce the extent of some coastal and nearshore habitats, while expanding others. For example, sandy and rocky beach habitats are vulnerable to conversion to open water (Smith and Liedtke 2022) while estuarine wetlands may expand (Glick et al. 2007). The vegetation composition of some freshwater wetlands will likely shift to more salt-tolerant vegetation as wetlands are inundated (Reeder et al. 2013), and increased water depths will alter light availability and potentially reduce eelgrass growth rates (Shaughnessy et al. 2012). In general, sea level rise is expected to reduce available nearshore habitat for forage fish (e.g., surf smelt, sand lance, Pacific herring), shellfish (e.g., Dungeness crab), and shorebirds and seabirds (Glick et al. 2007; Krueger et al. 2011).
	Hazard exposure grade: Medium
Sensitivity to Hazard and Adaptive Capacity of Natural Resources	While wetlands are largely tolerant of fluctuating water levels, those that have been heavily degraded or modified may be less likely to cope with increased water depths. Some habitats may be able to shift inland or upland as sea level rises, particularly in areas where their migration is not blocked by shoreline armoring or coastal development (e.g., bulkheads, roads) (Krueger et al. 2011; Mauger et al. 2015). This is unlikely throughout the majority of Sandy Point given the presence of homes, structures, and roads along the coast that restrict the ability of habitats to shift inland.
	Sensitivity grade: High **Adaptive Capacity grade:** Low
Vulnerability Summary	**Overall Vulnerability grade: Medium-High**

<table>
<tr><th colspan="2">Sandy Point Recreation</th></tr>
<tr><td>Assets Evaluated</td><td>▪ Sandy Point Marina
▪ Parks – Sandy Point Gardens, Sandy Point Swings, Sandy Point Tennis Court</td></tr>
<tr><td rowspan="2">Exposure to Hazard and Consequences</td><td>▪ Under existing conditions (i.e., no SLR), Sandy Point Gardens is expected to flood.
▪ 0.8 ft of SLR (2040-2060)
– Sandy Point Gardens, Sandy Point Swings, and Sandy Point Tennis Court expected to flood during king tides.
– Marina expected to flood during 20-year event.</td></tr>
<tr><td>Hazard exposure grade:
▪ Sandy Point Marina: Medium
▪ Parks: High</td></tr>
<tr><td rowspan="2">Sensitivity to Hazard</td><td>Increased frequency of flooding leads to water damage and other flood related damage for buildings like at the marina. Plants at the garden would likely be killed by saltwater inundation. Flooding would also cause loss of access to recreational amenities and associated commercial services. Flooding would disrupt access and potentially damage boats and docks at the marina.</td></tr>
<tr><td>Sensitivity grade:
▪ Sandy Point Marina: Medium
▪ Parks:
– High: Sandy Point Gardens
– Low: Sandy Point Swings and Sandy Point Tennis Court</td></tr>
<tr><td rowspan="2">Adaptive Capacity of Asset</td><td>Long-term operational interruption to the marina could occur if flooding or mechanical and plumbing systems are present on the ground floor and are subject to damage. Boats can often be relocated before a storm to reduce damage. Depending on park facilities, parks may be fairly adaptive to flooding and once water recedes, recreation can resume.</td></tr>
<tr><td>Adaptive Capacity grade:
▪ Sandy Point Marina: Medium
▪ Parks:
– High: Sandy Point Swings and Sandy Point Tennis Court
– Medium: Sandy Point Gardens</td></tr>
<tr><td>Vulnerability Summary</td><td>Overall Vulnerability grade:
▪ Sandy Point Marina: Medium
▪ Parks:
– Medium-High: Sandy Point Gardens
– Medium-Low: Sandy Point Swings and Sandy Point Tennis Court</td></tr>
</table>

	Sandy Point Community Vulnerability
Populations Evaluated	– Approximately 1,780 people live in Census Tract 9400.01, which includes Sandy Point and part of the northern extent of the Lummi Nation Reservation, according to 2021 American Community Survey estimates (U.S. Census Bureau 2021b). ▪ **Age:** The median age of residents is 46.8 years with approximately 15.6% under the age of 18 and 21.5% over the age of 65. ▪ **Disability:** About 16.6% of individuals report having a disability, of which 0.39% are under 18 years, 9.9% are between 18-64 years old, and 6.3% are 65 years and over. ▪ **Income:** The median household income is $68,333, per capita income is $39,435, and the poverty rate is 15.5%. ▪ **Housing Occupancy and Type:** There are approximately 971 housing units, 78% of which are occupied by either owners (80.7%) or renters (19.3%). These structures include single units (78.3%), multi-housing units (4%), and mobile homes (17.7%). ▪ **Computer and Internet Use:** Of occupied housing, approximately 98% have a computer and 92.6% have a broadband Internet connection. – Because this data was aggregated across the census block, it may be hiding subarea differences in vulnerability for different groups on and off the reservation.
Sensitivity to Hazard and Adaptive Capacity of Population	– Sea level rise and increased flooding is likely to affect communities by creating health, safety, and housing challenges. For example, increased coastal flooding may cause temporary or permanent displacement of residents and disruption to critical transportation routes for medical, food, and other services and supplies. Existing social and economic factors such as age, disability, income, housing, and access to information may amplify a community's sensitivity to sea level rise and flooding and challenge the ability to cope with or recover from these impacts. For example: ▪ **Age:** Children and seniors are typically more sensitive to sea level rise and flooding given existing health conditions, dependence on others for support, and reliance on critical services and infrastructure such as medical support, schools and daycares, and nursing homes or assisted living facilities. ▪ **Disability:** Residents with disabilities may have a harder time evacuating or accessing critical services due to disruptions to critical transportation routes. ▪ **Income:** Low-income residents are more at risk of displacement given resource constraints. Limited access to expendable income restricts the ability of these residents to rebuild and/or recover. ▪ **Housing Occupancy and Type:** Renters are typically more at risk of displacement than homeowners. Manufactured and mobile homes may be more susceptible to flood damage. ▪ **Computer and Internet Use:** Limited access to internet services can affect a resident's ability to effectively access emergency alerts and apply to and receive funding from recovery programs.
Vulnerability Summary	Fleming & Regan (2022) conducted a social vulnerability assessment as part of a larger sea level rise study for Puget Sound. This study created a composite index of multiple social and economic indicators (e.g., income, age, housing, access to services, etc.) to create a social vulnerability index score. The area from Birch Bay to the Lummi Reservation (including Sandy Point) ranked as having medium vulnerability overall, with a high vulnerability score associated with access to critical services, households living in poverty, and those with disabilities.

Appendix D.
Birch Bay Vulnerability Tables

	Birch Bay Parcels and Structures
Assets Evaluated	▪ North Whatcom County Fire Station ▪ Bay Center Market ▪ Structures (Homes/Businesses) ▪ Undeveloped parcels ▪ Unanchored Homes – North Bay Mobile Home Park – Birch Bay Resort Mobile Home Park – Edgewater Trailer Park ▪ Visitor Accommodations – Birch Bay Cottages – Worldmark Birch Bay – Beachcomber RV Park – Sandcastle at Birch Bay – Wyndham Birch Bay Resort – Beachside RV Park
Exposure to Hazard and Consequences	▪ Under existing conditions (i.e., no SLR), 16 structures expected to flood annually during king tides. ▪ **0.8 ft of SLR (2040-2060)** – 120 structures (116 of which are in South Birch Bay) and 54 undeveloped parcels expected to flood during king tides. – During the 20-year event, 384 structures, including Beachside RV Park and 71 undeveloped parcels expected to flood. – 4 structures in South Birch Bay expected to be in the erosion hazard zone by 2040 (see Section 4.4 for definition of erosion hazard zone). ▪ **3.3 ft of SLR (2080-2100)** – 1,315 structures, including structures within Birch Bay Cottages, Edgewater Trailer Park, Bay Center Market, Sandcastle at Birch Bay, Worldmark Birch Bay, Wyndham Birch Bay Resort, Beachcomber RV park, and 94 undeveloped parcels expected to flood during king tides. – During the 20-year event, 1,390 structures, and 97 undeveloped parcels expected to flood. – 22 structures and 7 undeveloped parcels expected to be in the erosion hazard zone by 2080. ▪ 1,444 structures and 100 undeveloped parcels expected to flood during the 100-year event with 6.6 ft of SLR. 48 structures and 9 undeveloped parcels expected to be in the erosion hazard zone by 2100.
	Hazard exposure grade: ▪ North Whatcom County Fire Station: n/a (does not flood under 100-yr storm and 6.6 ft of SLR) ▪ Bay Center Market: Medium ▪ Structures (Homes/Buildings): High (142), Medium (1.221), Low (75) ▪ Unanchored Homes – North Bay Mobile Home Park and Birch Bay Resort Mobile Home Park: n/a (does not flood under 100-yr storm and 6.6 ft of SLR) – Medium: Edgewater Trailer Park ▪ Visitor Accommodations – Medium: Birch Bay Cottages, Sandcastle at Birch Bay, Worldmark Birch Bay, Wyndham Birch Bay Resort, Beachcomber RV Park, Beachside RV Park ▪ Undeveloped Parcels: High (61), Medium (42), Low (3)
Sensitivity to Hazard	Increased frequency of flooding of structures leads to water damage and other flood related damage as well as disrupted access to and from buildings. Regular damage to visitor accommodations could impact tourism. Flooding of Bay Center Market, as main grocery store in the area, would reduce access to food without transportation. Flooding of unanchored homes would result in greater damage than anchored homes.
	Sensitivity grade: ▪ Bay Center Market: High ▪ Structures (Home/Buildings): Medium ▪ Unanchored Homes: High ▪ Visitor Accommodations: Medium ▪ Undeveloped Parcels: Low

Adaptive Capacity of Asset	Long-term operational interruption if flooding or mechanical and plumbing systems are present on the ground floor and are subject to damage. Residents of unanchored homes are more often on fixed incomes than anchored homes, making repairs/rebuilding more challenging.
	Adaptive Capacity grade: ▪ Bay Center Market: Medium ▪ Structures (Home/Buildings): Medium ▪ Unanchored Homes: Low ▪ Visitor Accommodations: Medium ▪ Undeveloped Parcels: High
Vulnerability Summary	**Overall Vulnerability grade:** ▪ Bay Center Market: Medium-High ▪ Structures (Homes/Buildings): Medium-High (142), Medium (1,221), Medium-Low (75) ▪ Unanchored Homes (Edgewater Trailer Park): Medium-High ▪ Visitor Accommodations: Medium ▪ Undeveloped Parcels: Medium-Low (94), Low (6)

Birch Bay Infrastructure

Assets Evaluated

- Birch Bay Water & Sewer District Facility
- Stormwater infrastructure (inlets, catch basins)
- Sewer infrastructure (manholes, lift stations)
- Fire hydrants
- Roads:
  - Birch Bay Drive
  - Salish Road
  - Nakat Way
  - Comox Road
  - Matsqui Place
  - Chehalis Road
  - Chehalis Place
  - Coquitlam Drive
  - Sehome Road
  - Sehome Court
  - Nitnat Way
  - Haida Way
  - Cowichan Road
  - Tsawwassen Loop
  - Nootka Loop
  - Birch Point Loop
  - Cedar Ave
  - Deer Trail
  - Shintaffer Rd
  - Beachway Drive
  - Halverson Ln
  - Cottonwood Dr
  - Cottonwood Ct
  - Harborview Rd
  - Club House Dr
  - Alderson Rd
  - Beachcomber Dr
  - Birch Dr
  - Birch Ln
  - Blaine Rd
  - Cedar Ln
  - Cotterill Blvd
  - Evergreen Ln
  - Fir Tree Ln
  - Francis Ln
  - Goldstar Dr
  - Jackson Rd
  - Leeside Dr
  - Lora Ln
  - Morrison Ave
  - Pine Dr
  - Pine Tree Ln
  - Piney Ln
  - Shady Ln
  - Sunset Dr
  - Terrill Dr
  - Timber Ln
  - Willow Dr
  - Wooldridge Dr

Exposure to Hazard and Consequences

- Under existing conditions (i.e., no SLR), 8 manholes and 1 fire hydrant flood during king tides.
- **0.8 ft of SLR (2040-2060)**
  - During king tides, much of Terrill Dr, Cotterill Blvd expected to flood, but <1 ft, so probably drivable (some flooding on Birch Bay Dr, Cedar Ave, Cottonwood Ct, Beachway Dr, Harborview Rd, Club House Dr, Birch Dr, Morrison Ave, Woodridge Dr, Jackson Rd too). About 30 feet of Birch Bay Dr in South Birch Bay and Jackson Rd flood >1 ft.
  - 23 sewer manholes, 19 stormwater inlets, 2 catch basins and 2 fire hydrants are expected to flood annually with king tides.
  - During 20-year event (5% chance of occurrence every year), Tsawwassen Loop, Sehome Rd, Cowichan Rd, Nootka Loop, Cottonwood Dr, Lora Ln, Francis Ln, Piney Ln, Alderson Rd, Sunset Dr expected to flood too, but all roads <1 ft flood depth so probably drivable.
  - 79 sewer manholes, 2 sewage lift station, 57 stormwater inlets, 18 catch basins, and 21 fire hydrants are expected to flood during the 20-year event.
- **3.3 ft of SLR (2080-2100)**
  - During king tides, much of Chehalis Rd, Chehalis Pl, Cowichan Rd, Sehome Rd, Sehome Ct, Nootka Loop, Birch Dr, Cotterill Blvd, Morrison Ave, Terrill Dr, Willow Dr, Wooldridge Dr flood >1 ft, so not drivable (some flooding of Halverson Ln, Birch Point Loop, and Coquitlan Dr too).
  - 189 sewer manholes, 7 sewage lift station, 112 stormwater inlets, 41 catch basins, 5 stormwater detention ponds, and 70 fire hydrants are expected to flood annually with king tides.
  - During 20-year event (5% chance of occurrence every year), Tsawwassen Loop, Birch Point Loop, Coquitlan Dr, Cowichan Rd, Salish Rd, Cedar Ave, Club House Dr, Cottonwood Ct, Birch Ln, Cedar Ln, Evergreen Ln, Fir Tree Ln, Lora Ln, Pine Dr, Pine Tree Ln, Piney Ln, Shady Ln, Sunset Dr, and Timber Ln becomes undriveable too (>1 ft of flooding). Nakat Wy, Nitina Wy, Cottonwood Dr flood too, but <1 ft flood depth so probably drivable
  - 203 sewer manholes, 8 sewage lift station, 117 stormwater inlets, 46 catch basins, and 78 fire hydrants are expected to flood during the 20-year event.
- During the 100-year event with 6.6 ft of SLR, 52 roads will be under >1 ft of water. 227 sewer manholes, 7 sewage lift station, 124 stormwater inlets, 49 catch basins, and 82 fire hydrants are expected to flood during the 100-year event.

	Hazard exposure grade: ▪ Birch Bay Water & Sewer District Facility: n/a (does not flood under 100-yr storm and 6.6 ft of SLR) ▪ Stormwater infrastructure (inlets, catch basins): Low to High depending on individual asset ▪ Sewer infrastructure (manholes): Low to High depending on individual asset ▪ Sewer infrastructure (lift stations): Medium ▪ Fire hydrants: Low to High depending on individual asset ▪ Roads: – High: Birch Bay Dr (in South Birch Bay), Jackson Rd – Medium: Chehalis Rd, Chehalis Pl, Cowichan Rd, Sehome Rd, Sehome Ct, Nootka Loop, Birch Dr, Cotterill Blvd, Morrison Ave, Terrill Dr, Willow Dr, Wooldridge Dr – Low: Remaining roads listed under “Assets Evaluated”
Sensitivity to Hazard	Flooding may disrupt access pathways critical for emergency services (such as access to fire hydrants) as well as transportation links to local businesses, residences, and municipal infrastructure. Flooding may lead to blockage of inlets or outlets. Tide gates are particularly susceptible to blockage due to high downstream water levels. Higher coastal water levels can cause insufficient capacity in the stormwater system for (potentially) increased rainfall. Failure of the storm drainage system can cause flooding inland of the coast and associated property damage as well as impacts to water quality. Flooding of sewer manholes or lift stations will likely impact the overall sewage system and could lead to overflows, which would impact water quality, or impacts to treatment systems.
	Sensitivity grade: ▪ Stormwater infrastructure (inlets, catch basins): Medium ▪ Sewer infrastructure (manholes): Medium ▪ Sewer infrastructure (lift stations): High ▪ Fire hydrants: Medium ▪ Roads: – Main ingress and egress (Birch Bay Dr): High – Other roads: Medium
Adaptive Capacity of Asset	Once water recedes, roads and stormwater infrastructure are likely to be operational fairly quickly. **Long-term operational interruption for lift stations if flooding or mechanical and plumbing systems are present on the ground floor and are subject to damage. The overall sewer system may require more time to get back online.**
	Adaptive Capacity grade: ▪ Stormwater infrastructure (inlets, catch basins): High ▪ Sewer infrastructure (manholes): High ▪ Sewer infrastructure (lift stations): Low ▪ Fire hydrants: High ▪ Roads: High
Vulnerability Summary	**Overall Vulnerability grade:** ▪ Stormwater infrastructure (inlets, catch basins): Medium-Low ▪ Sewer infrastructure (manholes): Medium-Low ▪ Sewer infrastructure (lift stations): Medium-High ▪ Fire hydrants: Medium-Low ▪ Roads: – Medium-High: Birch Bay Dr – Medium: Chehalis Rd, Chehalis Pl, Cowichan Rd, Sehome Rd, Sehome Ct, Nootka Loop, Birch Dr, Cotterill Blvd, Jackson Rd, Morrison Ave, Terrill Dr, Willow Dr, Wooldridge Dr – Medium-Low: Remaining roads listed under “Assets Evaluated”

Birch Bay Natural Resources	
Natural Resources Evaluated	▪ Kelp and eelgrass beds ▪ Beaches ▪ Wetlands ▪ Freshwater ponds ▪ Terrell Creek estuary
Exposure to Hazard and Consequences	– Sea level rise will reduce the extent of some coastal and nearshore habitats, while expanding others. For example, sandy and rocky beach habitats are vulnerable to conversion to open water (Smith and Liedtke 2022) while estuarine wetlands may expand (Glick et al. 2007). The freshwater ponds near Birch Bay Village will likely be completely inundated. The vegetation composition of some freshwater wetlands will likely shift to more salt-tolerant vegetation as wetlands are inundated (Reeder et al. 2013), and increased water depths will alter light availability and potentially reduce eelgrass growth rates (Shaughnessy et al. 2012). In general, sea level rise is expected to reduce available nearshore habitat in Birch Bay for anadromous fish (e.g., chum, coho, steelhead, resident coastal cutthroat), forage fish (e.g., surf smelt, sand lance, Pacific herring), shellfish (e.g., Dungeness crab), and shorebirds and seabirds (Glick et al. 2007; Krueger et al. 2011).
	Hazard exposure grade: Medium
Sensitivity to Hazard and Adaptive Capacity of Natural Resources	In general, while beaches and wetlands are largely tolerant of fluctuating water levels, those that have been heavily degraded or modified may be less likely to cope with increased water depths. Some habitats may be able to shift inland or upland as sea level rises, particularly in areas where their migration is not blocked by shoreline armoring or coastal development (e.g., bulkheads, roads) (Krueger et al. 2011; Mauger et al. 2015). This is unlikely in the majority of Birch Bay due to the presence of residential development and Birch Bay Drive. The southern area near Birch Bay State Park and Birch Bay Conservancy Area may be suitable for inland migration.
	Sensitivity grade: High **Adaptive Capacity grade:** Low
Vulnerability Summary	**Overall Vulnerability grade: Medium-High**

<table>
<tr><th colspan="5">Birch Bay Recreation</th></tr>
<tr><td>Assets Evaluated</td><td colspan="4">▪ Birch Bay Village Golf Course
▪ Birch Bay Village Marina
▪ Birch Bay Waterslides
▪ Parks:</td></tr>
<tr><td></td><td>– Sunset Park
– Lighthouse Park
– Marina View Park
– Dockside Park</td><td>– Sand Dollar Park
– Birch Beach
– Sunrise Park
– Kwann Lake Park</td><td>– Birch Bay County Park
– Cottonwood Beach County Park</td><td>– Birch Bay State Park (including Heron Center)
– Maple Street Beach Access</td></tr>
<tr><td rowspan="2">Exposure to Hazard and Consequences</td><td colspan="4">▪ Under existing conditions (i.e., no SLR), Birch Bay State Park is inundated during king tides.
▪ 0.8 ft of SLR (2040-2060)
– Birch Bay Golf Course, Sand Dollar Park, Birch Beach, Sunrise Park, and the Heron Center are expected to flood during the 20-year event.
▪ 3.3 ft of SLR (2080-2100)
– Birch Bay Golf Course, Sand Dollar Park, Birch Beach, and Sunrise Park expected to flood annually during king tides.
▪ During the 100-year event with 6.6 ft of SLR, Birch Bay Village Marina, Sunset Park, Lighthouse Park, Marina View Park, and Dockside Park flood.</td></tr>
<tr><td colspan="4">Hazard exposure grade:
▪ Birch Bay Village Golf Course: Medium
▪ Birch Bay Village Marina: Low
▪ Birch Bay Waterslides: n/a; not expected to flood under 100-year event with 6.6 ft of SLR
▪ Parks:
– High: Birch Bay State Park
– Medium: Sand Dollar Park, Birch Beach, Sunrise Park, and the Heron Center
– Low: Sunset Park, Lighthouse Park, Marina View Park, and Dockside Park</td></tr>
<tr><td rowspan="2">Sensitivity to Hazard</td><td colspan="4">Increased frequency of flooding leads to water damage and other flood related damage for buildings like the Heron Center. Flooding would also cause loss of access to recreational amenities and associated commercial services. Flooding would disrupt access and potentially damage boats and docks at the marina. Flooding of golf courses may impact buildings as well as greenways that are likely sensitive to saltwater inundation</td></tr>
<tr><td colspan="4">Sensitivity grade:
▪ Birch Bay Village Golf Course: Medium
▪ Birch Bay Village Marina: Medium
▪ Parks: Low</td></tr>
<tr><td rowspan="2">Adaptive Capacity of Asset</td><td colspan="4">Long-term operational interruption to the marina could occur if flooding or mechanical and plumbing systems are present on the ground floor and are subject to damage. Boats can often be relocated before a storm to reduce damage. Depending on park facilities, parks may be fairly adaptive to flooding and once water recedes, recreation can resume.</td></tr>
<tr><td colspan="4">Adaptive Capacity grade:
▪ Birch Bay Village Golf Course: Medium
▪ Birch Bay Village Marina: Medium
▪ Parks: High</td></tr>
<tr><td>Vulnerability Summary</td><td colspan="4">Overall Vulnerability grade:
▪ Birch Bay Village Golf Course: Medium
▪ Birch Bay Village Marina: Medium-Low
▪ Parks:
– Medium-Low: Birch Bay State Park, Sand Dollar Park, Birch Beach, Sunrise Park, and the Heron Center
– Low: Sunset Park, Lighthouse Park, Marina View Park, and Dockside Park</td></tr>
</table>

Birch Bay Social Vulnerability	
Populations Evaluated	Over 10,000 people live in Birch Bay (including parts of Drayton Harbor and south to Point Whitehorn Marine Park) according to 2021 American Community Survey estimates (U.S. Census Bureau 2021a). ▪ **Age:** The median age of residents is 46.9 years with approximately 18.6% under the age of 18 and 23.6% over the age of 65. ▪ **Disability:** About 17.5% of individuals report having a disability, of which 2.4% are under 18 years, 7% are between 18-64 years old, and 8.1% are 65 years and over. ▪ **Income:** The median household income is $65,729, per capita income is $40,176, and the poverty rate is 11%. ▪ **Housing Occupancy and Type:** There are approximately 5,713 housing units, 80% of which are occupied by either owners (77%) or renters (23%). These structures include single units (71%), multi-housing units (11.2%), mobile homes (17.1%), and other types (e.g., boat, van, RV; 0.8%). ▪ **Computer and Internet Use:** Of occupied housing, approximately 94.9% have a computer and 82.4% have a broadband Internet connection.
Sensitivity to Hazard and Adaptive Capacity of Population	– Sea level rise and increased flooding is likely to affect communities by creating health, safety, and housing challenges. For example, increased coastal flooding may cause temporary or permanent displacement of residents and disruption to critical transportation routes for medical, food, and other services and supplies. Existing social and economic factors such as age, disability, income, housing, and access to information may amplify a community's sensitivity to sea level rise and flooding and challenge the ability to cope with or recover from these impacts. For example: ▪ **Age:** Children and seniors are typically more sensitive to sea level rise and flooding given existing health conditions, dependence on others for support, and reliance on critical services and infrastructure such as medical support, schools and daycares, and nursing homes or assisted living facilities. ▪ **Disability:** Residents with disabilities may have a harder time evacuating or accessing critical services due to disruptions to critical transportation routes. ▪ **Income:** Low-income residents are more at risk of displacement given resource constraints. Limited access to expendable income restricts the ability of these residents to rebuild and/or recover. ▪ **Housing Occupancy and Type:** Renters are typically more at risk of displacement than homeowners. Manufactured and mobile homes may be more susceptible to flood damage. ▪ **Computer and Internet Use:** Limited access to internet services can affect a resident's ability to effectively access emergency alerts and apply to and receive funding from recovery programs.
Vulnerability Summary	Fleming & Regan (2022) conducted a social vulnerability assessment as part of a larger sea level rise study for Puget Sound. This study created a composite index of multiple social and economic indicators (e.g., income, age, housing, access to services, etc.) to create a social vulnerability index score. The area from Blaine to Birch Bay ranked as having low-medium vulnerability overall, with a medium-high vulnerability score associated with access to critical services, households living in poverty, and those with disabilities.

Appendix E. Potential Adaptation Measures

POTENTIAL ADAPTATION MEASURES

E-1 Protect – Soft Shore Techniques

E-1.1 Beach Nourishment

Beach nourishment is an adaptation strategy that provides protection against coastal storm erosion while maintaining the shoreline's natural condition, habitat, and processes (such as the ability of the beach to erode in response to winter coastal storms and build up sand in response to summer wave conditions). Beach nourishment refers to placement of sand or cobble to widen a beach, which can be accomplished by placing a sediment-water slurry directly on the beach or mechanical placement of sediment with construction equipment. Impacts to beach species can occur during construction but are expected to be temporary. Sediment can be obtained from inland sources (e.g., construction projects, quarries, etc.) and can be obtained for re-use from authorized offshore dredging projects, however, it can be difficult to find sediment supplies of the right quality (e.g., size, color, shape) for beach nourishment.

While beach nourishment initially reduces the risk of flooding and erosion along the beach, the beach width is expected to diminish with time, requiring an ongoing cycle of "re-nourishment" to maintain the beach. Additionally, while a wider beach reduces wave energy that reaches the shore, nourishment may not protect against flooding during high water level events. During large coastal storm events, sediment can be transported off the beach rapidly, reducing or eliminating the benefit of the nourishment. Additionally, the sediment can be transported into estuaries.

E-1.2 Habitat Restoration

Offshore kelp beds may dissipate waves to some extent but would not be very effective at maintaining sediment on the beach. Restoration of existing kelp beds can provide habitat benefits with some reduction in sediment movement downcoast. Restoring kelp beds requires a rock substrate and can be accomplished in areas with existing submerged rock or by placing rock offshore. With a focus on restoration of habitat, permitting of this strategy would likely be less complex than other sediment retention structures.

Wetland restoration in areas with existing or historic habitat would also help dissipate waves and protect inland development. Similar to kelp bed restoration, permitting could be less complex than other structural measures and would provide multiple benefits.

E-1.3 Coastal Bluff Erosion Best Management Practices

Best management practices (BMPs) for reducing coastal bluff erosion include management of surface drainage, shallow subsurface groundwater drainage to the bluff's edge and face, and vegetation to control local erosion and slope failure due to drainage. The goal of these practices is to control surface runoff and avoid concentrated flow down the bluffs, reducing shallow groundwater flow that saturates upper soils and facilitates erosion and can lead to bluff failure, and to facilitate management of groundwater daylighting (i.e., reaching the surface) at geologic layers. Vegetation intercepts rainwater and the roots can act to bind soil together, stabilizing the slope. This also includes protecting feeder bluffs that provide sediment to nearshore beaches through acquisition of and prevention of future development on these bluffs (e.g., Lily Point and Point Whitehorn in Whatcom County).

E-1.4 Large Wood Management

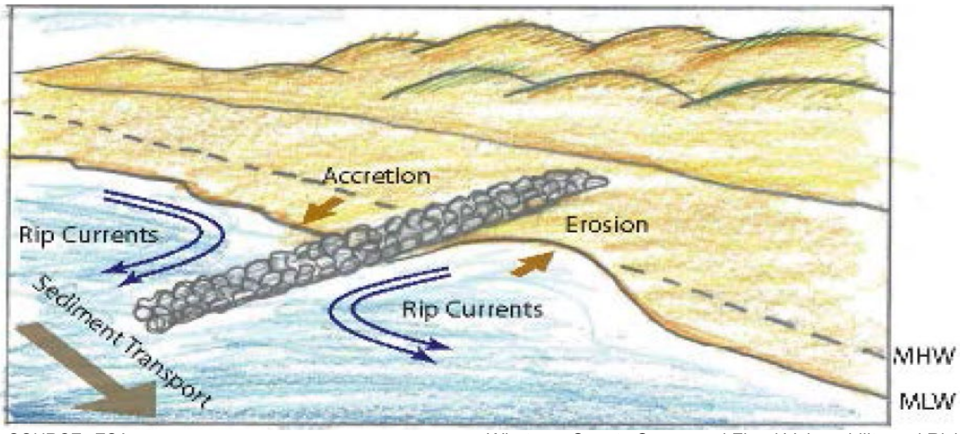
Large wood (e.g., tree trunks with and without rootwads) can reduce shoreline erosion rates while providing habitat benefits such as increasing aquatic productivity and habitat complexity. On a beach, large wood controls the elevation of the beach berm by holding sand in place. A higher beach berm results in reduced wave energy reaching the backshore. Managing existing large wood can lead to more wood recruitment, a reduction in wave-induced erosion, an increase in deposition in areas with aeolian sand transport, and increased species richness (Johannessen et al. 2014).

E-2 Protect – Hard Defensive Structures

E-2.1 Beach Retention Structures: Groins

Groins generally extend perpendicular to a beach and trap sediment from drifting downcoast (**Figure E-1**). Where wave conditions are ideal, groins have been successfully used in Washington and other locations to maintain a wider beach. In other cases, groins can induce and/or accelerate erosion downcoast of the groin, as shown in Figure 1. Groins are generally considered for placement along stretches of coast with high net longshore sediment transport. In application, groins separate the beach and nourishment efforts into segments, where sediment is mostly limited to the segment it is in. Drift Sills are a version of groins with lower height and less extents that allow sediment bypassing while inducing a subtle salient in shore planform and beach elevation (Johannessen et al. 2014).

Public access across or over groins has the potential to negatively affect lateral access along the beach. Constructing rock groins and other rock structures on the beach and/or in the ocean would alter the character of the natural shoreline and offshore habitats and have biological impacts to beach species. When first constructed, groins can significantly reduce the amount of sand transported down-current to neighboring beach areas as sand is trapped up-current of the groin. This impact can be somewhat mitigated if the area up current of the groin is partially filled with sand as part of construction. This can require significant amounts of imported sediment.



SOURCE: ESA

Whatcom County Compound Flood Vulnerability and Risk Assessment

Figure E-1
Example Processes Around Groins

E-2.2 Beach Retention Structures: Breakwaters

Breakwaters are offshore structures constructed parallel to a beach to reduce wave action. Typically built out of rock, breakwaters extend from the ocean floor to above the ocean level, thereby acting as a wall that blocks waves by causing them to break farther offshore. Breakwaters dissipate incident wave energy shoreward of the breakwater and change the pattern of sediment transport in their lee (i.e., wave shadow), thereby reducing the transport of sediment. These structures are generally applicable where there is a firm seabed and the need to create a calm area free from wave energy.

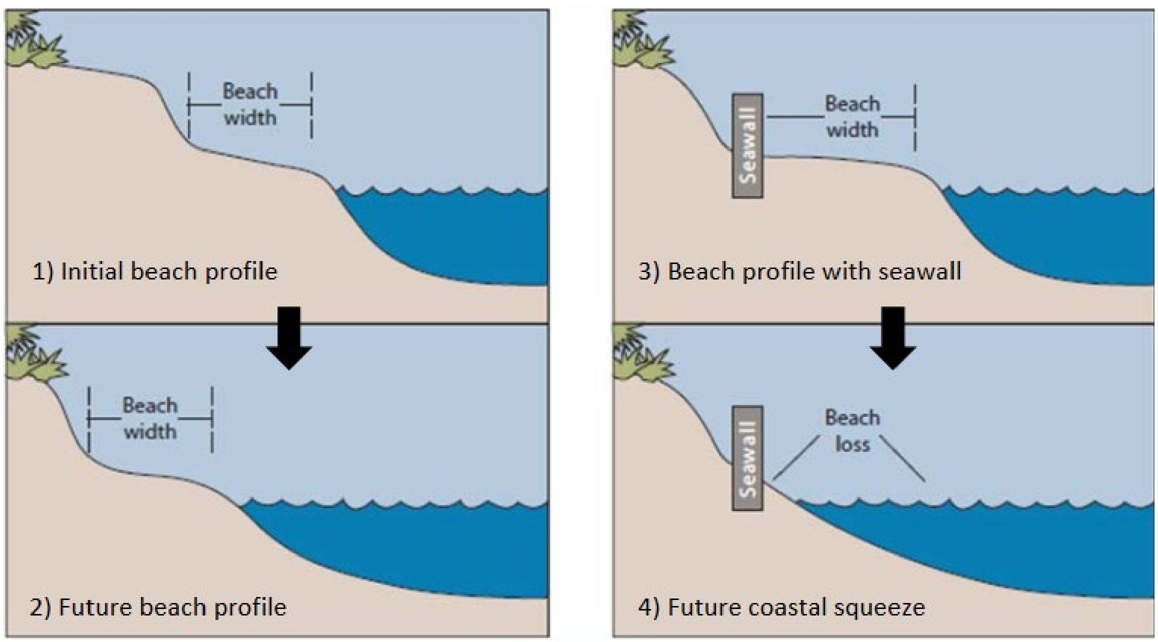
Breakwaters have been used to shelter shorelines and harbors, have been built in shorter segments to encourage sediment accumulation behind the breakwater segments, and in some instances can provide access and recreation. However, when first constructed they can starve down-current areas of sediment as sediment accumulates in front of the breakwater. Breakwaters can also displace and change ocean habitats and require significant permitting.

E-2.3 Shoreline Protection Devices

Shoreline protection devices, such as seawalls and rock revetments, are structures along the coast that provide flood and erosion protection for properties by absorbing or dissipating wave energy. Seawalls are vertical structures along a beach or coastal bluff used to protect structures and property from wave action. A seawall works by absorbing or dissipating wave energy. They may be either gravity- or pile-supported structures and are normally constructed of stone or concrete.

Revetments provide protection to slopes and are constructed of sturdy materials, such as stone. Similar in purpose to a seawall, revetments work by absorbing or dissipating wave energy. Revetments are made up of an armor layer (e.g., rock riprap piled up or a carefully placed assortment of interlocking material, which forms a geometric pattern), a filter layer (which provides for drainage and retains the soil that lies beneath), and a buried toe (which adds stability at the bottom of the structure).

While seawalls and revetments provide protection to existing shoreline development behind them, these structures can contribute to erosion and accelerate beach loss. The structures prevent the shoreline and bluffs from naturally eroding. Normally, waves lose momentum and energy as they run up a gently sloping shoreline, and sediment is deposited to form beaches. Many shoreline protection devices make it so that there is a hard back-stop to the shoreline. Waves hit the devices and reflect backward, rather than dissipating, often causing increased sand erosion in front of the device. They can also increase beach and bluff erosion on either side of the device and impact down-shore sediment supplies. With ongoing beach erosion and sea-level rise and without any other mitigating measures, fixing the shoreline location with a seawall or revetment will eventually lead to the loss of the beach seaward of the structure (**Figure E-2**).



SOURCE: California Coastal Commission, 2018 Whatcom County Compound Flood Vulnerability and Risk Assessment

Figure E-2
Coastal Squeeze Process Resulting in Beach Loss

Seawalls and rock revetments, in some cases, can have significant impacts on lateral acccess along the beach due to their displacement of beach area when they are constructed and the beach loss that can occur in front of and adjacent to these devices. In some cases they may also affect vertical access to the beach. Paths of access can be provided over and along the top of seawalls and revetments. It is more difficult, however, to climb one of these structures than to simply walk on the beach. Seawalls and rock revetments also can displace and change beach habitats, which is a particular concern in the Salish Sea ecosystem due to impacts to endangered salmonids and other species.

Additionally, using seawalls or rock revetments to "hold the line" on an eroding shoreline with sea-level rise may not be sustainable due to increasing wave action and overtopping associated with the loss of the fronting beach. However, in some locations beach nourishment could be implemented in conjunction with a seawall or revetment to at least partially offset this process for some time. Additionally, sea-level rise will require more frequent maintenance or reconstruction of these structures. Over time, the rocks of a revetment can move around and get washed onto the beach, reducing the effectiveness of the revetment and causing increased impacts to beach access. Permitting for these structures is challenging and the state is largely moving to reduce the use of hard armoring along shorelines due to their negative impacts; these structures may only be suitable in very specific instances.

Note that shoreline protection devices are designed to protect and withstand coastal storm events up to a certain severity, such as the "100-year storm event." Storm events that are more severe than the design events can cause flooding and damage.

E-3 Accommodate – Adapting in Place

E-3.1 Elevating or Waterproofing Structures and Infrastructure

Raising structures such as buildings, roads, and utilities is a measure that can shift infrastructure above coastal flooding elevations. Elevating structures can include raising buildings on pile foundations to allow for some limited migration and persistence of a fronting beach in the near-term. Raising roads and utilities could include replacing at-grade roads with pile-supported causeways. Associated utilities such as power, sewer, water, and electrical connections also need to be raised or waterproofed to avoid damage. Properties located in mapped flood hazard zones (pursuant to the FEMA Flood Insurance Rate Maps) are currently required to elevate the first floor above the base flood elevation. However, FEMA Flood Insurance Rate Maps do not account for the projected increases in flooding associated with sea-level rise or potential for increased flooding hazards in the future from changes in rainfall patterns as a result of climate change.

Raising buildings to address the flooding that results from infrequent coastal or riverine storm events can allow for the use of the buildings in between storm events. However, as sea levels rise and areas become more inundated from regular high tides or more frequent small coastal storm events, raising buildings on piles becomes ineffective as an adaptation strategy by itself because access to the structures would be restricted due to flooding of surrounding streets. Additionally, it could become hard to maintain services (e.g., water, wastewater, and electricity) to the structures. If measures such as beach nourishment and retention are not taken, the shoreline could continue to migrate past structures and potentially damage roads, infrastructure, and even the buildings if the pilings are undermined. In order to raise buildings in some areas, it may also be necessary to change height restrictions and other municipal code requirements. For beachfront properties where retaining a beach is a priority, raising buildings could be preferable to installing seawalls or revetments as it allows for the retention of structures for some time while still maintaining some beach area.

Building designs can also be modified so that the second floor is above the target flood level and contains all flood-sensitive features, while the first floor is used for parking and/or storage and is designed to be durable and resilient to flood damage. Abandoning the lowest floor or elevating the lowest habitable floor are effective strategies to reduce damage to the buildings from coastal or riverine storm events. This is often employed to meet FEMA base flood-elevation minimums for new construction, but lower thresholds could be established to require structural retrofits when remodeling is proposed.

Roads could be raised to avoid flood hazards. Infrastructure such as water and wastewater pipelines could be redesigned to be waterproof.

E-3.2 Elevating Property Grades

Raising buildings or roads could also be accomplished by placing fill to rebuild the grades at higher elevations. Utilities such as sewer pipelines and storm drains that are vulnerable to flooding, erosion, or increased groundwater levels can also be raised, so long as gravity flow is maintained, or pumps are installed. However, if one road is raised, all connecting roads, trails, and utilities would have to be rebuilt to slope up to the new grade. Elevating grades requires significant amounts of fill and, therefore, may only be feasible for areas of limited size. Additionally, filling an area changes the hydrology of both the area filled and the way rainfall runoff flows to neighboring areas. Stormwater would have to be managed effectively from the filled areas so as to not increase flood risks elsewhere, and this strategy may not be allowed in designated flood zones without compensatory mitigation.

E-4 Retreat

Managed retreat strategies are those strategies that deliberately plan to relocate or remove existing development out of hazard areas and limit the construction of new development in vulnerable areas. As buildings, utilities, and other infrastructure are increasingly at risk along beaches, coastal bluffs, or tidally inundated areas, removal or relocation to a less hazardous area is an effective adaptation strategy. Relocation requires sufficient and appropriate space. In some cases, this could require land acquisition. Removal or relocation can also be phased in to maintain at least some temporary use of the development or infrastructure as sea levels rise.

When considering removal or relocation of infrastructure and roads, a key consideration is how this would affect service and access to public and private properties remaining in hazard areas. If it becomes infeasible or uneconomical to maintain public services to private properties in hazard areas, many significant issues will need to be considered, including impacts to property owners and public safety.

Hazard avoidance can also be facilitated through development restrictions that are consistent with state statutes and state and federal constitutions.

Programs and policy options for retreat might include (Henderson 2018; Siders 2013; Spidalieri and Bennett 2020; Titus 2011):

- Acquisition and buyout programs
- Conservation easements

- Rolling easements/setbacks for development
- Rezoning, or modifications to zoning code
- Parcel restrictions
- Transfer of development right programs
- Defeasible estates (e.g., transfer of parcel ownership upon specific conditions being met such as a certain amount of sea level rise)
- Sea Level Rise Purchase Option (e.g., a real estate option that vests only when sea level rise affects a specific property, which would allow another entity to purchase the land)
- Fee simple acquisition and purchase with defined term lease back

Application of managed retreat to developed property may give rise to significant legal issues, including the potential for inverse condemnation liability. Implementation measures for managed retreat will require careful evaluation prior to adoption.

Throughout the United States, there are some examples of development removal and/or relocation programs sponsored by the FEMA. As part of the Hazard Mitigation Grant Program Acquisition Project, FEMA provides funds for local governments to purchase properties based on the principle of fair compensation from a willing, voluntary seller that have a structure that may or may not have been damaged or destroyed as a result of a hazard event. There is no readily available information regarding the effectiveness of this program and the extent to which it has already been applied.

Other issues that will need to be further considered in the future relating to retreat programs include existing federal and state laws concerning property ownership and takings of property. It is also unclear, based on current case law, how exactly property ownership boundaries (e.g., the location of state tidelands) could move as the shoreline erodes and the mean high tide moves inland from sea-level rise. The current state and federal laws governing property ownership, takings, and use of the coast were not written with consideration for large-scale changes such as sea-level rise. How these laws will be implemented and interpreted by the courts in the face of accelerated sea-level rise in the coming years is unknown. It is also possible that some of these laws will be amended in the future to address the issues caused by sea-level rise and other climate change hazards.

Retreat programs can also deepen social inequities by relying on cost-benefit analyses that promote disproportionate retreat in low-income or minority communities. Special consideration should be taken to mitigate these concerns (Siders 2018).

Additional federal and statewide policy, legal guidance, and information on funding mechanisms for managed retreat programs are likely needed to support the establishment of a private development removal program in Whatcom County. In upcoming years, the County could follow legal cases, legislative actions, and the development of removal or managed retreat programs in other jurisdictions throughout the United States and pursue studies of how such programs could be implemented in Whatcom County as more information becomes available.

E-5 Valuing Adaptation Measures

The adaptation scenarios discussed above were used to develop conceptual level engineering cost estimates for the structural and non-structural measures (**Table E-1**). The goal of engineering cost estimates is to achieve an understanding of the order of magnitude of costs. These conceptual estimates are based on ESA's experience with similar projects and are not meant to substitute for a detailed engineering cost estimate that may be completed as part of a more specific adaptation plan in the future. Costs associated with retreat, large infrastructure replacements/upgrades, and policy and programmatic measures were not included in this conceptual cost comparison because such estimates would require additional specificity.

TABLE E-1 CONCEPTUAL ENGINEERING COST ESTIMATES FOR POTENTIAL ADAPTATION MEASURES IN WHATCOM COUNTY, WA

Adaptation Measure	Conceptual Cost	Description
Protect – Hard Defensive Structures		
Groins	$$$	Requires extensive in-water work and complex permitting review.
Breakwaters	$$$	Requires extensive in-water work and complex permitting review.
Shoreline Protective Devices:		
Seawall	$$-$$$	Usually poured concrete applied to a section of shoreline. Cost dependent on length.
Rock Revetment	$$-$$$	Riprap or gravel placed in layers along a stretch of coastline. Cost dependent on the size and amount of rock needed.
Protect – Soft Shore Techniques		
Beach Nourishment	$$	Applied to eroding shorelines. Cost highly dependent on total cubic yardage needed and availability of sediment.
Habitat Restoration	$$	Marine, estuarine, and riverine work (e.g., kelp beds, wetlands, lower watershed)
Coastal Bluff Erosion BMPs	$	Surface drainage management on top of and along bluffs
Accommodate – Adapting in Place		
Waterproofing	$$-$$$	May include new or retrofitted infrastructure.
Elevating Structures	$$$	In flood or wave zone.
Elevating Property Grades	$$$	Cost to deliver and compact fill. Cost dependent on total quantity.